Chapter 5
Elementary and Secondary Education

Highlights

The quality of mathematics and science education in the United States has been an ongoing concern of scientists, engineers, and decisionmakers. Following World War II, scientists, engineers, and mathematicians expressed grave concerns in the Bush and Steelman reports about the quality of pre-college instruction in their fields as well as the number of students who go on to college and study these subjects. They saw the curriculum as badly out of date, too broad for teachers to master—let alone students—and instruction as too passive for children to develop a genuine understanding of the key concepts and ideas in their fields. The perception of a crisis in education was further created by the launching of Sputnik in 1957 and by the publication of international comparative studies of student achievement starting in the 1970s. Pre-college math and science education is today still a national, state, and local concern. The following highlights point out that some improvements have occurred on a national scale, but that these are not uniform. Additionally, international comparisons show that U.S. achievement is especially low at the end of secondary school, well below the international average.

U.S. Achievement Compared with Other Countries

- **U. S. student achievement in mathematics and science compared least favorably with that of their peers in other countries at the end of high school, was at or above the international average in middle school, and was above the international average in elementary school in the 1995 Third International Mathematics and Science Study (TIMSS).**
- **U.S. students in the final year of secondary school scored below the international average on assessments of general science and mathematics.** On an assessment of general mathematics, students in 14 of 21 nations outperformed U.S. students, and on an assessment of general science, students in 11 of 21 countries outperformed U.S. students. The United States performed better than 2 countries, Cyprus and South Africa, in both subjects.
- **U.S. 12th grade advanced science students performed below 14 of 16 countries on the TIMSS physics assessment. Advanced mathematics students scored below 11 of 16 countries on the advanced mathematics assessment.** Advanced mathematics and science students did not outperform students in any country on either the physics or advanced mathematics assessment.
- **Eighth grade U.S. science students performed above the 41-country international TIMSS average.** They performed at the international average in chemistry and physics, and above average on life sciences, earth sciences, and environmental issues.
- **Eighth grade U.S. mathematics students performed below the 41-country international average overall as well as in geometry, measurement, and proportionality.**
- **The science and mathematics performance of fourth grade students in the United States was among the highest of those countries participating in the TIMSS assessment at that level.** In science, fourth grade students scored well above the international average for 26 countries overall as well as in the four content areas assessed. Fourth grade students scored above the international mean in mathematics overall and in all content areas except measurement.

National Trends in Achievement

- **U.S. students in the 1990s were generally performing better in mathematics and science as measured by the National Assessment of Educational Progress (NAEP) than did their counterparts in the late 1970s.** The "benchmarks" selected for this report are scores on NAEP trends assessment of 200, 250, and 300, respectively, for ages 9, 13, and 17.
- **The science and mathematics achievement of both male and female students has increased in the last two decades at all ages tested (9, 13, and 17).**
- **No significant difference in mathematics performance was observed between boys and girls at ages 9 and 13 between 1978 and 1996.** Differences in mathematics performance for 17-year-old males and females were observed in NAEP between 1978 to 1986, but not between 1990 and 1996.
- **No gender differences in mathematics were observed at any grade in the international assessment administered for the TIMSS.**
- **Gender differences in science achievement continue to exist in the 1996 NAEP for students at ages 13 and 17.** Differences between boys and girls in science achievement in the United States were generally small compared with differences for students in other countries (TIMSS).
- **The percentage of white, black, and Hispanic students that reached the benchmark levels of science achievement at ages 9, 13, and 17 increased between 1977 and 1996.** The change was particularly noteworthy for

9-year-old black students, who increased by 25 percentage points over that period.

- **White, black, and Hispanic students in the three age groups demonstrated upward trends for mathematics proficiency between 1978 and 1996.** Differences in achievement levels of racial and ethnic groups persist, however.

Advanced Course Taking by High School Students

- **More students took advanced mathematics and science courses in 1994 than in 1982.** More than 90 percent of the high school class of 1994 completed biology, more than one-half completed chemistry, and about one-quarter completed physics. Approximately 70 percent of the class of 1994 completed geometry, 58 percent completed algebra 2, and 9 percent completed calculus.

- **Students from racial/ethnic groups that are typically underrepresented in science and mathematics made substantial gains in the proportions taking advanced mathematics and science courses.** For example, the proportion of black students completing chemistry doubled between 1982 and 1994; the completion rate for Hispanic students nearly tripled; and for American Indian/Alaskan Natives, the proportion increased by more than one-half. More students in all racial/ethnic groups completed physics between 1982 and 1994, although the proportion of students from black, Hispanic, and American Indian/Alaskan Native groups remained lower than for white and Asian students in 1994.

Curriculum and Instruction

- **Access to technology in schools grew rapidly in the 1990s.** Hand-held calculators are in common use in both U.S. homes and classrooms. Computers are seemingly ubiquitous and Internet connectivity is on the increase. By 1998, nearly all schools reported having at least one computer linked to the Internet and half of individual classrooms had access to the Internet. However, at present, only about one teacher in five felt "very well prepared" to integrate education technology into the subjects they taught.

- **A "digital divide" persists in access to technology in schools.** Black and Hispanic students and less affluent students continue to have less access to high-end technology at school.

- **Curriculum and textbooks used in U.S. schools are highly repetitive, contain too many topics, and provide inadequate coverage of important topics, according to a curriculum analysis conducted as a part of TIMSS.** Independent judges determined that none of the 9 U.S. science texts that were evaluated and only 6 of the 13 U.S. mathematics texts were satisfactory based on 24 instructional criteria.

- **Instruction in U.S. eighth-grade classrooms focuses on development of low-level skills rather than on understanding and provides few opportunities for students to engage in high-level mathematical thinking.** A team of mathematicians found that 13 percent of Japanese lessons in 1995 were judged to be of low quality while 87 percent of lessons from U.S. classrooms were judged to be of low quality.

Teachers and Teaching

- **There are few adequate indicators of the quality of teachers to describe teaching in the United States.**

- **It is common for students to be taught mathematics and science by teachers who do not hold degrees in these subjects.** For example, a 1996 study showed that more than a third of eighth graders were taught mathematics by teachers who had neither a degree in mathematics nor a degree in mathematics education. This mismatch was even larger in science.

Alternative Forms of Schooling

- **Charter schools now serve approximately 170,000 students out of 48 million students in the United States.** From school year 1992/93 to 1997/98, the number of charter schools increased from 2 (in Minnesota) to approximately 1,000 nationwide.

- **More low-income students have access to privately funded vouchers and scholarships.** In school year 1992/93, close to 4,100 low-income students in four urban districts received privately funded vouchers or scholarships to attend better schools. In school year 1996/97, approximately 11,000 low-income students in 28 urban districts received private scholarships.

- **Increased numbers of parents are choosing to educate their children at home.** Home schooling has increased from an estimated 250,000 to 350,000 nationwide in 1991/92 to approximately 700,000 to 750,000 in 1995/96.

Introduction

The U.S. education system encompasses over 15,000 school districts and 88,000 public schools (NCES 1999a). Under the Constitution, educational matters are the province of the states, which delegate certain decisions to school districts or other local education agencies. Local decision making gives rise to local differences in instructional practices, which in turn yield differences in achievement. It is useful to keep this point in mind throughout the following discussion.

The statistical information presented in this chapter has been selected from representative national surveys, most of which were collected and published by the National Center for Education Statistics (NCES), an agency of the U.S. Department of Education.

Chapter Organization and Sources of Data

This chapter begins with a brief discussion of education-reform efforts that began in the 1950s. The remainder of the chapter is organized into four main sections, each addressing a critical aspect of mathematics and science education reform.

Student Achievement. This section discusses student achievement from both national and international perspectives. It is based on two primary sources of data: National Assessment of Educational Progress (NAEP) trends studies, which provide the Nation's only continuous comparable measures of student performance in four core subjects in the United States—reading, writing, mathematics, and science. They have been administered to nationally-representative samples of 9-, 13-, and 17-year-old students every two to four years since 1969. NAEP results have been reported in terms of performance levels only since 1977, which is the point where this chapter begins tracking NAEP achievement. Second, the Third International Mathematics and Science Study (TIMSS) provides information about representative samples of students in the primary and middle grades as well as students in their final year of secondary school. TIMSS includes several components: assessments in science and mathematics from 41 nations, student and teacher surveys, an analysis of curriculum guides and textbooks from 26 nations, and an observational-video study conducted in eighth grade mathematics classrooms in the United States, Germany, and Japan.

Patterns of Course Taking. This section describes the extent to which students of different gender and ethnicity completed higher-level mathematics and science courses in 1994 as compared to earlier years. The data are taken from the 1994 High School Transcript Study (HSTS). Results are based on the records of over 25,000 seniors who graduated between 1982 and 1994 (NCES 1998e).

Curriculum and Instruction. This section of the chapter discusses instructional time, curriculum and textbooks, instructional practice, and technology. Information is drawn from the curriculum and component of TIMSS as well as NCES Fast Response Surveys on telecommunications technology and classroom implementation of educational reforms.

Teachers and Teaching. This section provides an overview of teacher characteristics and qualifications, estimates of the proportion of teachers with classes outside their fields, and a discussion of new directions in teacher preparation, licensing, and professional development. Primary sources for this discussion are a recent NCES Fast Response Survey on teacher qualifications and recent educational literature pertaining to the policy aspects of teaching.

Educational Reform from the 1950s to the Present

As the National Science Foundation (NSF) celebrates its 50th year and the new millennium approaches, the Nation has identified educational reform as one of its highest priorities. Large-scale education reform in the United States has been attempted many times. However, it is quite a difficult undertaking—much more so than in other nations—due to the greater size and complexity of the U.S. system and the greater diversity of our students.

The roots of current reform efforts can be traced to developments that took place in the 1950s and 60s. Early in that era, even before the launching of Sputnik in 1957, scientists and mathematicians expressed grave concerns about the quality of precollege instruction in their fields. Among other things, they saw curricula as badly out of date and instruction as too passive for children to develop genuine understanding of the key concepts and ideas in their fields. (See sidebar, "View of Mathematics and Science Education in Elementary Schools in 1947.") With support from NSF, small groups of scientists and mathematicians began designing radically different curricula. The University of Illinois Committee on School Mathematics, under the leadership of Max Bebberman, began work on a new curriculum for high school mathematics. The Physical Science Committee, under the leadership of Jerald Zacharias, began working on new science curricula in their field (Bybee 1997, Dow 1997, and Rutherford 1997). Later, other groups of scientists came together to work on curricula for biology and chemistry.

With the launching of Sputnik, concerns about mathematics and science education reached crisis proportions. The American public joined scientists and educators in calling for reform, believing that U.S. schools were graduating too few talented scientists and engineers to assure the security of the Nation. There were two dominant views how instruction should be overhauled. Mathematicians and scientists thought the solution involved elevating academic standards and curriculum. Others argued for a return to past educational practices—reflecting a "back to basics" philosophy. The latter position was argued perhaps most vocally by Admiral Hyman Rickover, here cited by Dow (1969, 59):

> We are engaged in a grim duel. We are beginning to recognize the threat to American technical supremacy, which could materialize if Russia succeeds in her ambitious program of achieving world scientific and engineering supremacy by turning out vast numbers of well-trained scientists and engineers.

> We have let our educational problem grow far too big for comfort and safety. We are beginning to see now that we must solve it without delay.

NSF responded to the perceived crisis by expanding its work in curriculum development. With NSF support, curriculum projects proliferated in the early 1960s. (See sidebar, "National Science Foundation Support of Post-Sputnik Reforms in Science and Mathematics Education.") According to Shymansky, Kyle, and Alport (1983), the science programs were successful. By the early 1970s, NSF-funded science curricula for grades 7 through 12 were used in 60 percent of school districts and materials for elementary grades were used in 30 percent of the school districts. Because the new curricula were difficult to implement, by 1976/77, only 30 percent of districts continued to use one or more of the new science programs. New mathematics curricula fared less well, used in only 30 percent of districts in the early 1970s and in only 9 percent in 1976/77 (Bybee 1997).

The United States turned its attention to other matters until another crisis in education was declared early in the 1980s. During those years, numerous reports were published that were highly critical of the U.S. educational system. The most influential of the reports was *A Nation at Risk* (NCEE 1983):

> Our nation is at risk. Our once unchallenged prominence in commerce, industry, science, and technological innovation is being taken over by competitors throughout the world.…While we can justifiably take pride in what our schools and colleges have historically accomplished and contributed to the United States and the well-being of its people, the educational foundations of our society are being eroded by a rising tide of mediocrity that threatens our very future as a nation and as a people. What was unimaginable a generation ago has begun to occur: others are matching and surpassing our educational attainments.

A Nation at Risk provided several recommendations for improving the nation's schools including increasing the requirements for graduation, increasing instructional time in core subjects, lengthening school days and school years, significantly improving teaching, and developing and implementing rigorous and measurable standards. Different initiatives were undertaken in response to these recommendations. State policy makers implemented the "new core" curriculum proposed in *A Nation at Risk*, which required four years of English, three of mathematics, three of science, three of social studies, and one-half year of computer science. High school students were required to pass exit examinations in order to receive diplomas and assure that they had command of fundamental academic skills. In the 1970s, only a handful of states required exit exams. By 1990 at least 40 states had adopted this practice (Geisinger 1992). Schools were required to develop and monitor their progress on improvement plans. More stringent screening and certification requirements were put in place in an effort to upgrade the quality of teaching (Popkewitz 1992).

Other reform initiatives focused on the structure of decisionmaking and power relationships among teachers, principals, district administrators, and parents. In many school districts, decision making was decentralized based on the assumption that those closest to the children in a school were best equipped to identify and meet the children's learning needs. School-based management and a variety of other approaches to restructuring schools were tried (Peterson 1992). New models of professional development were proposed (Sparks and Loucks-Horsley 1990, Darling-Hammond 1994) and initiatives to "professionalize" teaching were promoted, many of which focused on empowerment strategies.

The development of standards ushered in the current decade of educational reform, one that has been centered on content and instructional strategies. The National Council for Teachers of Mathematics was first to develop new standards for student learning (NCTM 1989) and teaching (NCTM 1991). The standards provided guidelines for instruction and

View of Mathematics and Science Education in Elementary Schools in 1947

It is better to teach a few things for mastery than to spread the effort over a larger number of goals, some of which are doubtful.

Present-day textbooks in arithmetic are thick and include a wide range of materials, and the unskilled teacher has difficulty determining the things that are important. The teacher may not have a clear notion (1) of the new mathematical terms that should be mastered in a given semester, (2) of the new principles that should be learned, (3) of the skills that should be gained, (4) of the concepts that should be carefully taught, and (5) of the attitudes that should be established.

[The] practical limitations to the teaching of arithmetic are

(1) the oversized classes of 30, 40, or even 50, when they should probably be held to approximately 20,

(2) failure of teachers to have and to utilize classroom materials and equipment,

(3) the tendency of teachers to forget the long trail that they themselves have traveled to arrive at generalizations and at the meaning of symbolism,

(4) the fact that many teachers undertake the teaching of arithmetic with no training in arithmetic beyond what they had in elementary school,

(5) the utilization of conflicting methods by teachers in the same school system or in the same building,

(6) the lack of specific objectives in arithmetic, and

(7) the failure of the teacher to take each pupil where he is and to provide experiences in accord with his normal growth and development.

SOURCE: Steelman, J.R. 1947. *Science and Public Policy*. Washington, DC: U.S. Government Printing Office. Reprinted 1980. The University of California, Irvine. New York: Arno Press.

National Science Foundation Support of Post-Sputnik Reforms in Science and Mathematics Education

One of the primary forces shaping the science reforms of the 1950s and 1960s was the National Science Foundation. Founded in 1950, the NSF's education effort prior to Sputnik had been confined to promoting science fairs and clubs and funding summer institutes for teachers. In 1955, the NSF annual report expressed growing concern about the shortage of high school students entering scientific careers, but was reluctant to lobby Congress for funds given the nation's historic aversion to federal influence in school matters. While the Foundation had cautiously supported Jerrold Zacharias' early planning work on PSSC Physics at M.I.T., it took the launching of Sputnik to release a torrent of federal funds.

In 1958, the NSF increased its support for curriculum development at a rapid pace; in addition to supporting PSSC, the organization funded the School Mathematics Study Group at Yale and the Biological Sciences Curriculum Study of the American Institute of Biological Sciences. Within the next two years, the organization also launched two programs in high school chemistry: the Chemical Bond Approach Project and the Chemical Education Materials Study of the American Chemical Society. By 1960, the programs of the Education Directorate represented 42 percent of the NSF annual budget. Each of these projects, at NSF's insistence, was guided by a steering committee of prominent scientists and engineers....

If the movement had lasted longer, it may have had a wider impact on schools. Unfortunately, by the end of the decade, federal support for curriculum innovation was beginning to wane … What finally killed the science reform movement, however, was the Apollo moon landing in 1969. When the world saw Neil Armstrong unfurl the American flag on the surface of the Moon, our 'education gap' seemed as mythological as the so-called 'missile gap,' and ironically congressional support for science education began to fade. Before the mid-seventies, the Education Directorate of the National Science Foundation had shrunk to 10 percent of the agency's budget, and following election of President Reagan in 1980, the Directorate closed altogether. The Sputnik reforms were to prove as ephemeral as the technological threat that spawned them.

SOURCE: Dow, P. 1997. "Sputnik Revisited: Historical Perspectives on Science Reform. Prepared for the symposium, "Reflecting on Sputnik: Linking the Past, Present, and Future of Educational Reform." Washington, DC. October 4.

learning, building upon earlier reports issued by the Mathematics and Science Education Board (MSEB) of the National Research Council (NRC) and the Mathematical Association of America (MAA). The science standards followed several years later (NRC 1996). Although not formally released by the NRC until 1995, the science education standards reflected a consensus arrived at earlier and built upon work of the National Science Teachers Association (NSTA) and the American Association for the Advancement of Science (Rutherford and Algren 1990). The seminal reports of these associations are included in the list of references (NSTA 1992, NRC 1996, and AAAS 1999a,b).

Central to standards in both subjects is the idea that students must become what Robert Glaser has described as "mindful architects of their own knowledge" (cited in Maloy 1993). In this constructivist view, students play a proactive role in their learning, rather than passively receiving information doled out by teachers or textbooks. The teacher's primary role is to facilitate and support the process by creating opportunities for students to engage in higher-level processes—solve novel problems, integrate information, and actively build their own understanding of a particular idea or situation (Anderson 1996). The standards for mathematics and science, share several basic tenets, including:

- ♦ promoting high expectations for all students;
- ♦ emphasizing depth rather than breadth of content coverage; and
- ♦ emphasizing tasks that provide students the opportunity to become actively engaged with the subject matter, problem solving, and applying skills learned in new, broader contexts.

Many of the core ideas underlying new educational standards in science and mathematics are legacies of the 1960s reform agenda, but there are important differences. One such difference is that the factor motivating change during the post-Sputnik years was the perceived need to expand the pool of potential scientists. Consequently, curricula developed during that period targeted students at the higher end of the achievement spectrum. By contrast, as educational reform evolved in the late 1980s and early 1990s, there was a genuine interest in providing a high quality education for all students. In contemporary reforms, equity and excellence are treated as equally important goals (DeBoer 1997 and Rutherford 1997).

Current reform efforts differ from earlier attempts in the breadth of their activity. From the 1960s through the 1980s, many reform strategies were pursued in isolation: some approaches focused solely on curriculum, some focused solely on structural change, and some focused exclusively on teachers. In the 1990s, the idea that all parts of the education system must be changed to meet new standards and goals was formalized in an often-cited publication by Smith and O'Day (1991), which put forward the notion of "systemic" approaches to reform. Such methods are grounded in three core ideas:

promotion of high standards for all students, purposeful alignment of policies to support good instructional outcomes, and restructuring of governance systems around the goal of improved achievement (Smith and O'Day 1991).

The sidebar, "Systemic Reform: Complex Solutions to Complex Problems," describes the intricacies involved in systemic reform, as conceptualized by NSF in the late 1970s, although the term "systemic reform" was not yet in common use.

Federal agencies have actively supported systemic reform, with the systemic initiatives funded by NSF among the best known efforts. In the first cycle of the program, NSF awarded grants to support state level reforms aimed at improving instruction and raising academic achievement. Later, the program was extended to support systemic reform in urban communities, then in rural communities, and most recently, local reform at the school district level. The U.S. Department of Education's Eisenhower Initiatives complemented these efforts, providing funds for the kind of high quality professional development needed to achieve high standards.

Legislation, particularly the "Goals 2000: Educate America Act," has bolstered the idea of large-scale reform. At the core of Goals 2000 are the eight National Education Goals that grew out of educational summits organized by the nation's governors, then-President Bush and later, President Clinton. The national goals as they appear in the legislation are presented in the sidebar, "The National Education Goals."

The legislation provides funds for states to pursue national goals through comprehensive reform efforts that encompass development and implementation of challenging standards, content, and assessments; strengthening professional development; and aligning governance strategies and accountability systems to be consistent with academic goals (Landess 1996).

The Social Context of Education

Learning experiences in schools, as elsewhere, are conditioned by the social context in which they occur. For schools, social context is greatly influenced by characteristics of the children in attendance. School enrollment is viewed as an indicator of the demand for teachers, facilities, and resources. In 1950, approximately 25 million students were enrolled in public elementary and secondary schools (NCES 1998a). The 1999 enrollment is expected to include 33.7 million elementary school students and 13.5 million secondary students. Public school enrollment is projected to be 48 million students by the year 2009 (NCES 1999a). (See figure 5-1 and text table 5-1.)

The composition and diversity of the school population have increased in the last several decades and projections suggest that these trends will continue into the 21st century. Hispanic students made up 7 percent of the school population in

Systemic Reform: Complex Solutions to Complex Problems

….[T]here are too many complex, interconnected problems present for any one, simple solution to alter the fundamental dynamics of teaching and learning in the overall education system or even a single classroom…. Clear standards for science education…that give life and meaning to classroom practice are an important part of the answer, but real, sustainable change demands much more:

- ♦ A transformation of people's beliefs about science education well informed by the processes of science and by our evolving understanding of children's ability to learn complex, thought-provoking material;
- ♦ The creation in each district and school of a clear vision of effective science teaching and a set of goals that reflects this evolving knowledge;
- ♦ High-quality instructional materials that support a coherent presentation of important science concepts—and the resources necessary to make those materials available to every student;
- ♦ New kinds of tests that more accurately measure students' deep understanding of ideas, not just their short-term recall of facts;
- ♦ A long-term commitment of professional development to a generation of educators capable of turning this vision of teaching and learning into reality;
- ♦ A broadening of public understanding and support for effective science education and the development of community partnerships that spur schools, universities, museums, foundations, and corporations to work toward common goals;
- ♦ Steadfast support from district administrators and policymakers who recognize the crucial importance of local school-based initiatives;
- ♦ Enlightened leadership that understands how all of these factors affect and depend upon each other; and
- ♦ The need for all of these changes to occur at the same time.

This is the soul of a systemic approach to science education reform: a wide-angle view of school change that sees all aspects of the system as a whole. It recognizes that if changes are to be long lasting, each and every component part of the system must be irreversibly and permanently altered.

SOURCE: National Science Foundation (NSF). 1997a. "Foundations: A Monograph for Professionals in Science, Mathematics, and Technology Education." In *The Challenge and Promise of K-8 Science Education Reform, Volume 1*. NSF 97-76. Washington, DC.

The National Education Goals

By the year 2000:

1) All children in America will start school ready to learn.

2) The high school graduation rate will increase to 90 percent.

3) American students will leave grades 4, 8, and 12 having demonstrated competency in challenging subject matter…including mathematics and science.

4) The Nation's teaching force will have access to programs for the continued improvement of their professional skills and the opportunity to acquire the knowledge and skills needed to instruct and prepare all American students for the next century.

5) U.S. students will be first in the world in mathematics and science achievement.

6) Every adult American will be literate and will possess the knowledge and skills necessary to compete in a global economy and exercise the rights of citizenship.

7) Every school in the United States will be free of drugs, violence, and the unauthorized presence of firearms and alcohol and will offer a disciplined environment conducive to learning.

8) Every school will promote partnerships that will increase parental involvement and participation in promoting the social, emotional, and academic growth of children.

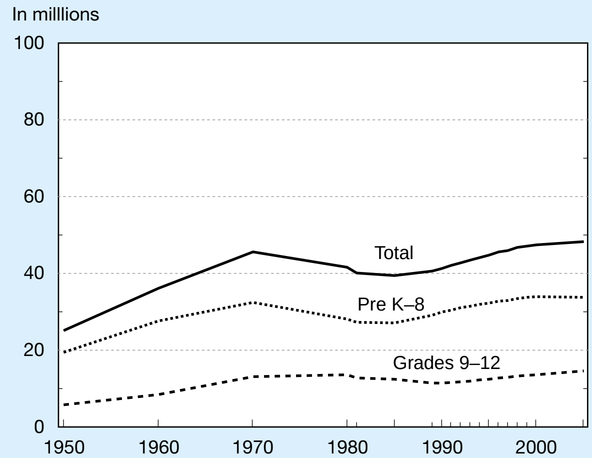
SOURCE: U.S. Department of Education. 1999. Educational Excellence for All Children Act of 1999. Fact sheet. Available from <<http://www.ed/gov/offices/OESE/ESEA/factsheet.html>>. Accessed August 12, 1999.

1979 and 14 percent in 1996. Growth in the percentage of black students in the public school population was more modest: 15 percent in 1970, 16 percent in 1979, and 17 percent in 1995, with concentrations of both ethnic groups much higher in central city schools. In 1996, approximately 32 percent of students in central city schools were black and 25 percent were Hispanic (NCES 1999c). (See text table 5-2.)

More language diversity has been introduced into schools as the number of immigrant and Hispanic students has increased. Recent data show more school-aged children now live in non-English speaking homes than ever before. That number has increased steadily from 2.9 million in 1980 to 4.2 million in 1990 (NCES 1998b).

Several family characteristics associated with school success also have changed in recent years. Mothers of younger children were better educated in 1997 than in 1972. Fewer mothers had less than a high school diploma, a decrease from 34 percent to 16 percent over that period, and more mothers were employed, 38 percent in 1972 vs. 66 percent in 1997. Fewer children lived in large families (four or more siblings),

Figure 5-1.
Total enrollment in public elementary and secondary schools: 1950–2005



SOURCE: U.S. Department of Education, National Center for Education Statistics, Statistics of State School Systems; Statistics of Public Elementary and Secondary School Systems; Statistics of Nonpublic Elementary and Secondary Schools; Projections of Education Statistics to 2007; Common Core of Data. National Center for Education Statistics (NCES). 1999. *Digest of Education Statistics,* 1998. NCES 1999-036. Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

See appendix table 5-1. *Science & Engineering Indicators – 2000*

Text table 5-1.
Total enrollment in public elementary and secondary schools: 1981–2009, selected years

Year	Total	Prekindergarten through grade 8 (in thousands)	Grades 9 through 12
Fall 1981	40,044	27,280	12,764
Fall 1985	39,422	27,034	12,388
Fall 1990	41,217	29,878	11,338
Fall 1995	44,840	32,341	12,500
Fall 1999[a]	47,244	33,701	13,543
Fall 2000[a]	47,533	33,875	13,658
Fall 2005[a]	48,392	33,723	14,669
Fall 2009[a]	48,126	33,427	14,699

[a]Projected.

SOURCE: National Center for Education Statistics (NCES). 1999. *Projections of Education Statistics to 2009.* NCES 1999-038. Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

Science & Engineering Indicators – 2000

Text table 5-2.
Percentage of students in grades 1–12 who are black or Hispanic in all public schools and public schools within central cities: 1970–96, selected years

	Black		Hispanic	
Year	Total	Central cities	Total	Central cities
1970	14.8	32.5	—	—
1979	16.1	35.8	6.8	14.0
1985	17.0	36.0	10.1	21.5
1990	16.5	33.1	11.6	19.8
1994	16.8	33.0	13.4	24.7
1995	17.1	31.8	14.0	24.3
1996	17.0	31.9	14.3	25.0

SOURCE: National Center for Education Statistics (NCES). 1999. *The Condition of Education, 1999.* NCES 1999-022. Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

— Not available

Science & Engineering Indicators – 2000

a decrease from 24 percent to 6 percent. (See appendix table 5-4.)

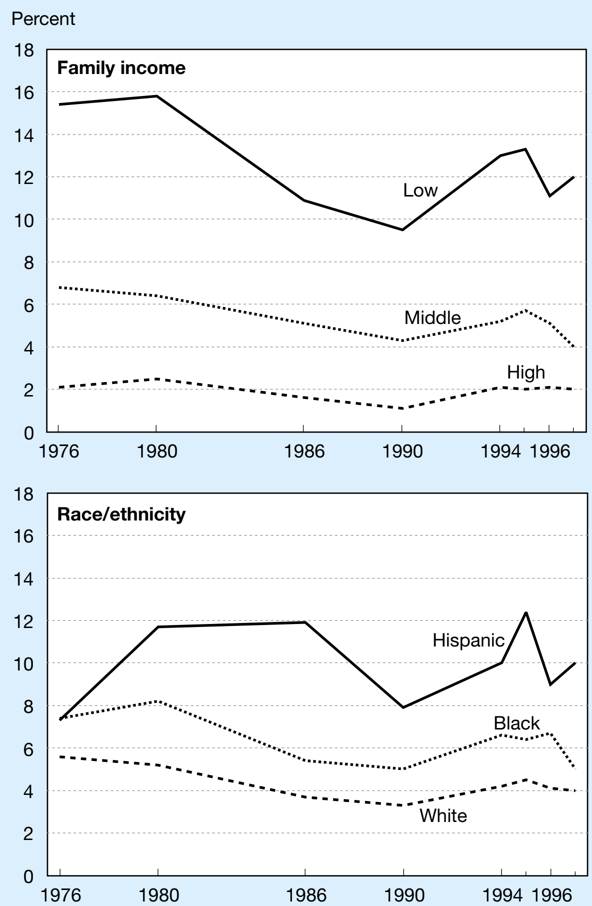
Not all changes reflected improved circumstances. Median family income[1] dropped from $38,000 in 1989 to approximately $35,000 in 1995 and 1996 (Peterson 1992) and the number of poor children has increased. In 1970, approximately 10 million children under 18 years of age (15 percent) lived in families with earnings below the poverty level. In 1996, 14 million children (20 percent) lived in poverty. (See appendix table 5-1.) Black and Hispanic children were more likely to live in poverty than white children. For example, in 1996, approximately 40 percent of black and Hispanic children (4.4 and 4.1 million, respectively) lived below the poverty line, compared to 16 percent of white children (8.5 million).

Although diversity adds richness to the learning environment, it also presents special challenges. Poor and minority children and children with limited English proficiency are more likely to experience difficulty in the early grades, to repeat a grade, or to need special education services (NCES 1998b). Black, Hispanic, and low-income students also are more likely to leave school without a high school diploma. (See figure 5-2.) Of those who complete high school, black students and low income students are less likely to enroll in college following graduation (NCES 1999c).

Additionally, families are more mobile, another factor related to poor school outcomes. The National Center for Education Statistics (NCES) estimates that one in three students changes schools more than once between first and eighth grades (NSB 1999). These moves sometimes seriously disrupt the continuity of learning, making it difficult for teachers in the new schools to identify and meet the academic needs of these highly mobile students (Kelly, Suzuki, and Gaillard 1999; NSB 1999).

As the National Science Board (1999) pointed out, responding to these challenges may be the most difficult task faced by schools and teachers in the next century. In their view, it is no longer acceptable for race, ethnicity, gender, language, or

Figure 5-2.
Percentage of 15 to 24-year-olds (grades 10–12) who dropped out of school, by family income and race/ethnicity: 1976–97



SOURCE: National Center for Education Statistics (NCES). 1998. *The Condition of Education 1998.* NCES 98-013. Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

See appendix tables 5-2 and 5-3.

Science & Engineering Indicators – 2000

[1]Median incomes are computed in 1996 dollars adjusted by the Consumer Price Index.

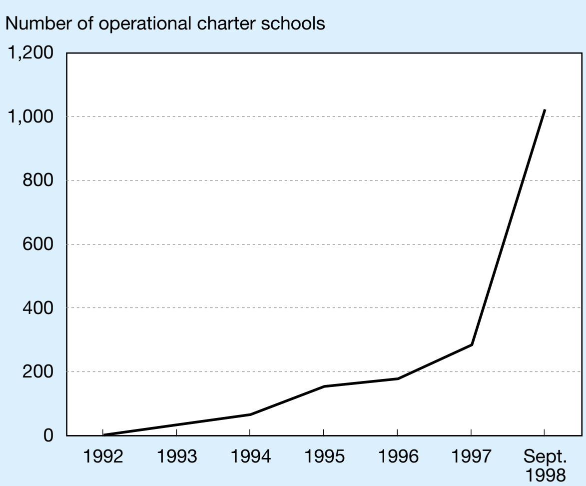
economic disadvantage to be used as excuses for the poor academic achievement of particular groups of children.

Schooling and School Choice in the 21st Century

Even with the thrust toward national standards and national goals—and perhaps in some cases *because* of that thrust—the balance of control over education is changing rapidly as the 21st century approaches. Where the option is available, many parents are enrolling their children in charter schools. Charter schools operate under a contract (or charter) with a public agency, most often a local school district. The charter frees the school from state and local regulations that might otherwise limit their use of innovative approaches to instruction. In return, the school agrees to meet specific achievement goals within a specific time period, usually three to five years. If the targets are not met, the charter is not renewed.

The number of charter schools varied considerably over states in 1998, from 5 or less in Mississippi, Hawaii, Rhode Island, Nevada, New Mexico, Delaware, and South Carolina, to over 100 in California, Michigan and Arizona (CSU 1998). In the years since the first two charter schools opened in Minnesota in 1992, the number of schools operating by charter has grown steadily. (See figure 5-3 and appendix table 5-5). Currently, the number of charter schools in operation is estimated at between 1,022 (Berman 1998) and 1,200 (Hadderman 1998 and CER 1999) nationwide. According to recent estimates, these schools serve 170,000 students, still a small proportion of the approximately 47 million elementary and secondary students in the United States.

Figure 5-3.
Charter schools by year



SOURCE: California State University (CSU). 1998. *Charter Schools: National Concept, California Experience.* Proceedings of a roundtable discussion sponsored by the California Education Policy Seminar and the California State University Institute for Education Reform. Sacramento, CA. October 1.

See appendix table 5-5. *Science & Engineering Indicators – 2000*

Educational vouchers are another mechanism for choice. The idea was first proposed in the 1950s by economist Milton Friedman, who argued that schools would upgrade the quality of their offerings (or go out of business) if they had to compete for students and resources (Hadderman 1998). Today, vouchers are promoted as a way to move central city children from failing schools to more successful schools. But vouchers remain controversial on several fronts. One of the most contentious issues is whether large-scale voucher systems will deplete much needed resources from public schools. Another point of dispute centers on the appropriateness and legality of using public funds to send children to private and religious schools. A number of privately-financed voucher plans, generally given in the form of scholarships, also have made an appearance in recent years. According to estimates, in 1992/93 approximately 4,100 privately-financed scholarships were offered to low-income students in four urban districts; in 1996/97, close to 11,000 needy students in 28 urban districts received private scholarships (Hadderman 1998).

Home-schooling also has increased in recent years—from an estimated 250,000 to 350,000 students nationwide in 1991/92 to approximately 700,000 to 750,000 students in 1995/96 (Lines 1996). Home schooling is generally seen as the ultimate form of school choice. In the 1970s, home schooling was a prevalent choice among families committed to a philosophy of child-led learning. Later, families chose to educate their children at home for religious reasons. Currently, issues of school safety and local control over curriculum also are prompting more parents to choose this alternative (Lines 1996). Students taught at home generally attend a campus-based school at least part-time for special subjects and special activities. Community resources and nearby colleges are drawn on to round out home programs of study (Lines 1996).

Although almost all states require families to register their children as "home schoolers," other regulations vary by state. Some states require parents to submit instructional plans for home-schooled students to the local or state education agency. Some require home-schooled children to participate in state testing programs. Few regulations exist, however, to assure that parents have some minimal level of educational experience in order to teach their own children at home. In most states, parents are not required to have teaching certificates to educate their own children at home. Michigan, which has the most stringent regulations, only requires the involvement of a certified teacher.

To date, few systematic studies have been conducted to determine achievement outcomes in charter schools. Published results have not been consistent from place to place or from one study to another. By contrast, home schooling has shown consistently positive results. In virtually every comparative study undertaken, home-schooled students outperformed their public schools counterparts. This finding is viewed with some caution however, because by necessity, data are available only from states that require home-schooled children to participate in testing programs (Lines 1996). No large-scale studies of voucher programs have been conducted, but that situation will soon change. In response to a request by the U.S. Department of Education, the National Research Council has proposed a comprehensive study that will not only examine the achievement of students whose education is financed or supplemented by vouchers, but will also examine the policy consequences, such as the impact vouchers have on the public school system (White 1999).

Student Achievement

Trends in National Achievement

The National Assessment of Educational Progress (NAEP) has monitored educational performance through its trends series (which is distinguished from other NAEP series) since 1969. To facilitate comparisons, the same instruments have been used in every trend assessment since that time. NAEP trend results are reported in terms of average scale scores and in terms of five proficiency levels or anchor points. The five anchor points correspond to five levels of performance, ranging from the basic skills and knowledge to be mastered in the earliest years (Skill Level 150) to the fluency needed to solve challenging problems (Level 350). Most of the NAEP results included in this chapter are based on the latter. (See sidebar, "Proficiency Levels Used in NAEP Science and Mathematics Trends Assessments.")

NAEP trends results from the last 20 years indicate that, for the most part, students are performing at higher levels in mathematics and science than did their counterparts in the late 1970s. However, the data also suggest that performance falls below expectations based on new educational standards (NCES 1997a).

Elementary and Middle School Science and Mathematics

At the high school level, the primary function of the mathematics and science curricula is to begin the preparation of future scientists, mathematicians, and engineers, which was the goal of educational reforms in the 1960s. In turn, the primary function of elementary and middle school science and mathematics is to lay the groundwork for high school curricula in these areas. In other words, elementary and middle schools are expected to provide the building blocks that students will need in order to progress through the science and engineering pipeline in later years. These early years are quite critical, particularly for mathematics. According to several respected educators, it is in elementary school that young children begin constructing a knowledge base to build upon as they progress to higher levels of knowledge, skill, and understanding (Campbell and Johnson 1995). This section of the chapter examines the adequacy of elementary, middle, and high school preparation, as reflected by NAEP achievement results.

The science and mathematics achievement of both 9- and 13-year-old students has improved significantly since 1977/78. In science, about two-thirds of 9-year-olds reached Level

Proficiency Levels Used in NAEP Science and Mathematics Trends Assessments

Level	Science	Mathematics
350	**Integrates Specialized Scientific Information** Can infer relationships and draw conclusions using detailed scientific knowledge.	**Multistep Problem Solving and Algebra** Can solve multistep problems and use algebra.
300	**Analyzes Scientific Procedures and Data** Has some detailed scientific knowledge and can evaluate the appropriateness of scientific procedures.	**Moderately Complex Procedures and Reasoning** Can compute with decimals, fractions, and percents; recognize geometric figures; solve simple equations; and use logical reasoning to solve problems.
250	**Applies General Scientific Information** Understands and applies general information from the life and physical sciences.	**Numerical Operations and Beginning Problem Solving** Can add, subtract, multiply, and divide using whole numbers and can solve one-step problems.
200	**Understands Simple Scientific Principles** Understands some simple principles and has some knowledge, particularly about physical sciences.	**Beginning Skills and Understanding** Can add and subtract two-digit numbers and recognize relationships among coins.
150	**Knows Everyday Science Facts** Knows some general science facts.	**Simple Arithmetic Facts** Knows some addition and subtraction facts.

SOURCE: National Center for Education Statistics (NCES). 1997. NAEP 1996 Trends in Academic Progress. NCES 97-985. Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

200 in 1977, showing that they could understand some simple scientific principles. Between 1977 and 1996, the proportion reaching this level increased so that on the most recent assessment, roughly three-quarters of students demonstrated that capacity. Approximately 26 percent of 9-year-olds met or exceeded Level 250 in 1977, showing that they could apply general information from the life and physical sciences. That number increased to 32 percent in 1996.

The proportion of 13-year-old students reaching achievement Levels 200 and 250 in science also increased between the first and the most recent trends assessments. Eighty-six percent or more of 13-year-olds showed understanding of simple scientific principles (Level 200) in 1977, while 92 percent performed at the level in 1996. Level 250 performance demonstrates some capability to apply life- and physical-science concepts. Approximately 49 percent of 13-year-olds reached or exceeded that level in 1977 and about 58 percent did so in 1996. (See figure 5-4.)

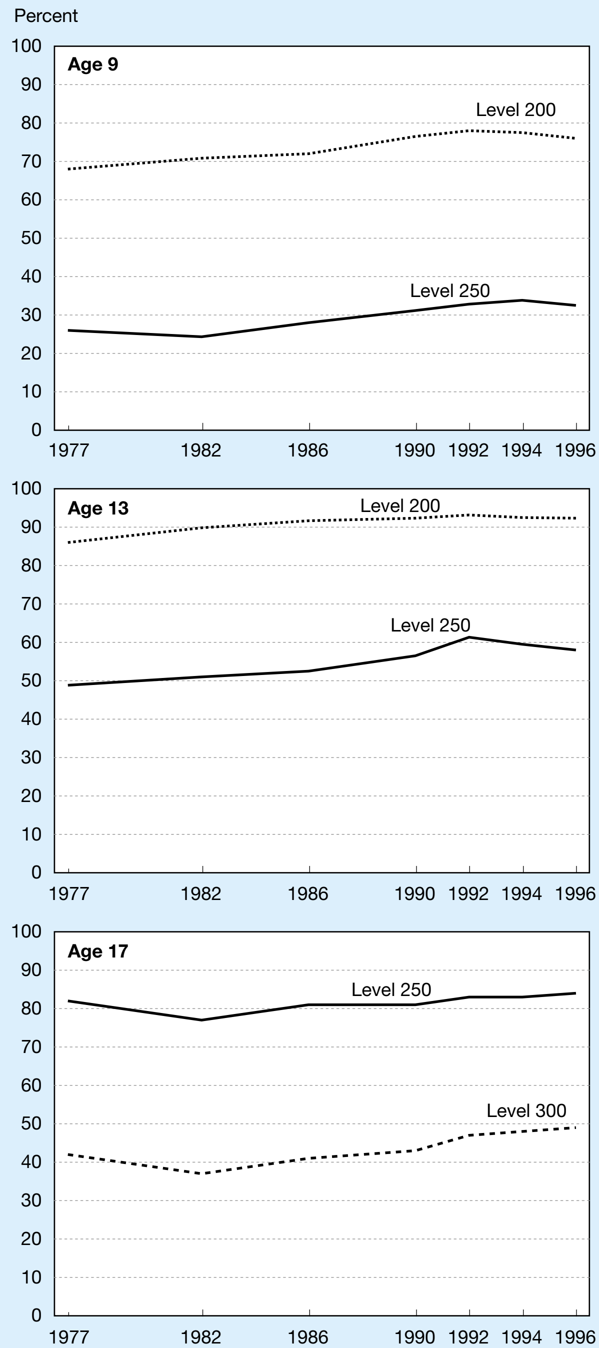
The mathematics achievement of elementary and middle school aged children also improved between 1978 and 1996. (See figure 5-5.) At Level 200, students are able to add and subtract two-digit numbers and recognize some coins. The percentage of 9-year-olds achieving that level was 70 percent in 1978 and increased to 82 percent in 1990, after which it remained stable through 1996. At Level 250, students can perform the basic four mathematical operations (addition, subtraction, multiplication, and division) and can solve one-step problems. In 1978, approximately 20 percent of 9-year-olds performed at this level. The numbers grew to 30 percent in 1996.

The number of 13-year-olds demonstrating command of the basic operations of mathematics (Level 250) grew from 65 percent in 1978 to 79 percent in 1996. At Level 300, students are able to compute with decimals and fractions, recognize geometric figures, solve simple equations, and use moderately complex reasoning. Approximately 18 percent of students demonstrated these skills in 1978 compared to 21 percent in 1996, which was not significantly higher.

High School Achievement

There were also some gains among 17-year-old students in science and mathematics from 1977 to 1996. (See figures 5-4 and 5-5.) In 1977, 82 percent of 17-year-olds met or exceeded Level 250 on the science assessment, the stage at which students can apply principles of life and physical sciences. There was an upward trend in the performance of students achieving at this level between 1977 and 1996, but the 84 percent in 1996 was not significantly different from the 1977 findings. Forty-two percent of 17-year-olds achieved Level 300 in 1978, where students are presumed to have some detailed scientific knowledge and the capacity to evaluate the appropriateness of scientific procedures. The percentage of high school students demonstrating benchmark performance ranged from 37 percent in 1982 to 48 percent in 1996. The overall pattern of science performance increase between 1977 and 1996 performance was significant. (See figure 5-4.)

Figure 5-4.
Trends in the percentage of students at or above benchmark levels of NAEP science performance, by age: 1977–96



NAEP = National Assessment of Educational Progress

SOURCE: National Center for Education Statistics (NCES). 1997. *NAEP 1996 Trends in Academic Progress.* NCES 97-985. Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

See appendix tables 5-6, 5-7, and 5-8.

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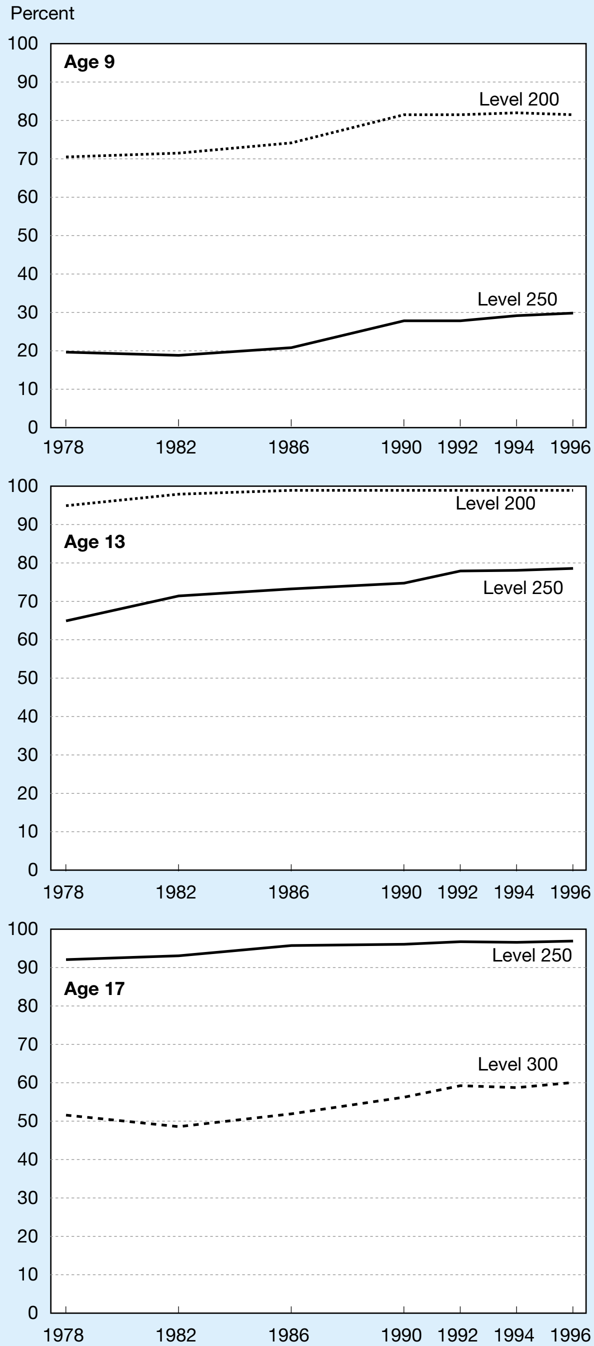
Figure 5-5.
Trends in the percentage of students at or above benchmark levels of NAEP mathematics performance, by age: 1978–96



NAEP = National Assessment of Educational Progress

SOURCE: National Center for Education Statistics (NCES). 1997. *NAEP 1996 Trends in Academic Progress.* NCES 97-985. Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

See appendix tables 5-9, 5-10, and 5-11.

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In 1978, approximately 92 percent of 17-year-old students functioned at or above Level 250 in mathematics, showing that they could solve one-step problems. (See figure 5-5.) The 5 percentage-point difference between the 1977 numbers and the overall upward trend were statistically significant. Approximately 52 percent of 17-year-old students functioned at a higher complex reasoning stage (Level 300) in 1978 and 60 percent in 1996, a statistically-significant increase in the change of percentage points.

Achievement Trends by Demographic Group

The proportion of females and underrepresented minorities still remains low at every point along the science, mathematics, and engineering pipeline. For these reasons, it is of interest to monitor mathematics and science performance of these demographic groups from elementary school through high school.

Gender Differences in Performance. The chapter on higher education reports that the number of females who receive bachelor's degrees in natural science fields has increased in the past ten years but that the number of women in mathematics and computer science fields has not increased since 1985. Therefore, the performance of students on mathematics tests in elementary and secondary school is of concern as an indicator of the preparation of students for college performance in mathematics and science.

NAEP performance levels for male and female students are presented for science in text table 5-3 and for mathematics in text table 5-4. A higher proportion of both male and female 9-year-olds reached benchmark science performance in 1996 than in 1978. Between 1977 and 1996, the performance levels of boys and girls were not distinguishable. For 13-year-olds, significant increases also occurred for both boys and girls between 1977 and 1996; however, at this age, boys have slightly higher proportions with performance in science above 250 (62 percent of boys and 54 percent of girls). At age 17, the performance of both males and females increased between 1977 and 1996 but males were more likely than females to get scores of 300 or more in 1996. (See text table 5-3.) By 1996, the difference in the proportion of males and females scoring at 300 or more was about 9 percentage points. Thus, in science performance, the tendency of males to perform at higher levels than females at older ages continues to exist.

In mathematics, differences between males and females are much more difficult to detect than for science. At ages 9 and 13, the percentage of males and females reaching the benchmark on the mathematics assessment (Level 200 at age 9 and 250 at age 13) increased from 1978 to 1996. There had been no significant difference for boys and girls age 13 since 1978. For 17-year-olds, the mathematics performance of both genders increased significantly from 1978 to 1996 but the differences in the performance of male and female students has not formed a consistent trend. The figures in text table 5-4 suggest a closing of the gap between males and females (males were a few percentage points higher in 1978, 1982,

Text table 5-3.
Trends in the percentage of students at or above benchmark levels of science performance, by age and sex: 1977–96, selected years

Years	Male	Female
Age 9	Level 200	
1977	70	67
1982	70	72
1986	74	70
1990	76	76
1992	80	76
1994	78	77
1996	77	76
Age 13	Level 250	
1977	52	45
1982	56	46
1986	57	48
1990	60	53
1992	63	60
1994	62	57
1996	62	54
Age 17	Level 300	
1977	49	35
1982	45	30
1986	49	34
1990	48	39
1992	51	42
1994	53	42
1996	53	44

SOURCE: National Center for Education Statistics (NCES). 1997. *NAEP 1996 Trends in Academic Progress*. NCES 97-985. Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

See appendix tables 5-6, 5-7, and 5-8.

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Text table 5-4.
Trends in the percentage of students at or above benchmark levels of mathematics performance, by age and sex: 1977–96, selected years

Years	Male	Female
Age 9	Level 200	
1978	69	72
1982	69	74
1986	74	74
1990	81	82
1992	82	81
1994	82	82
1996	83	81
Age 13	Level 250	
1978	64	66
1982	71	71
1986	74	73
1990	75	74
1992	78	78
1994	79	77
1996	80	77
Age 17	Level 300	
1978	55	48
1982	52	45
1986	55	49
1990	58	55
1992	61	58
1994	60	57
1996	63	58

SOURCE: National Center for Education Statistics (NCES). 1997. *NAEP 1996 Trends in Academic Progress*. NCES 97-985. Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

See appendix tables 5-9, 5-10, and 5-11.

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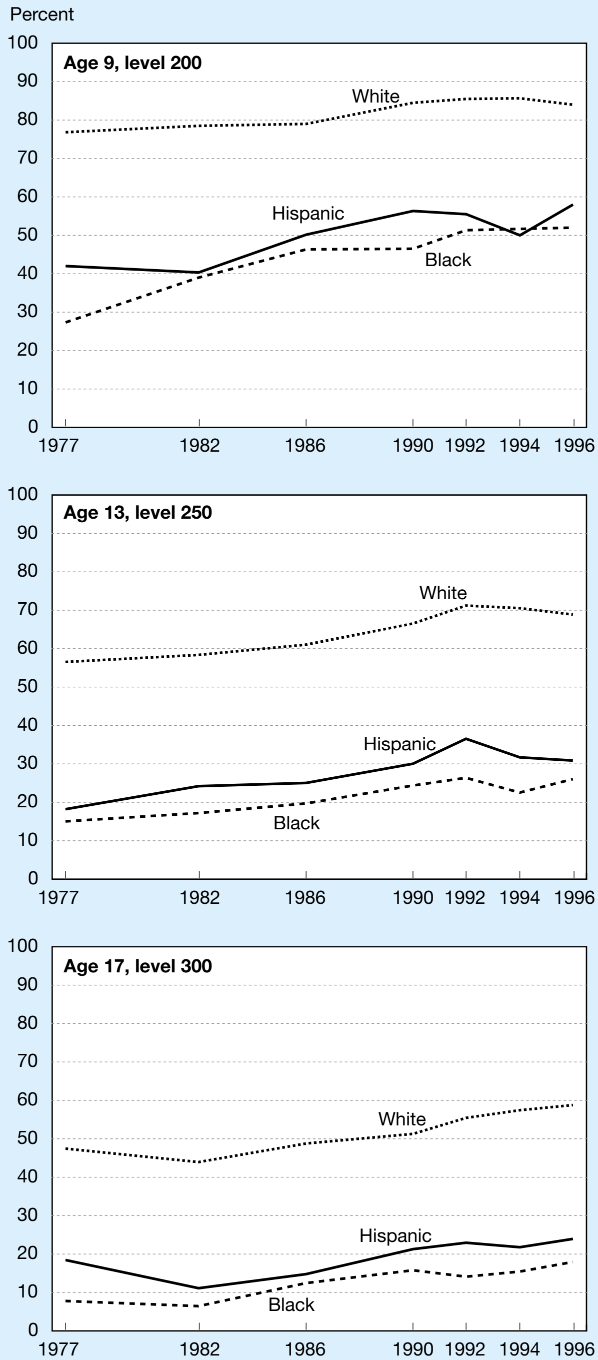
and 1986), but no evidence of a further closing of the gap was observed between 1990 and 1996. Among 17-year-olds, males increased their achievement in the 1990s whereas females did not have significant increases in performance between 1990 and 1996. The apparent difference between male and female 17-year-olds in 1996 was not statistically significant.

Gender differences in student performance on mathematics and science assessments were also examined globally in the reports of Third International Mathematics and Science Study for grades 4, 8, and 12. The comparative performance of boys with that of girls depends on the subject and grade level for most countries. In science, boys outperform girls in most countries in middle school (28 out of 39 countries) and in high school (in 20 out of 21 countries), but not in as many countries at elementary levels (10 out of 25). In mathematics, boys are much less likely to outperform girls in elementary school (3 out of 25 countries) or middle school (8 out of 39 countries), but at high school age, boys outperformed girls in 18 out of 21 countries. Interestingly, U.S. performance on the TIMSS assessments revealed no gender differences at any grade in mathematics. There were some differences detected between U.S. boys and girls in science at elementary and high school grades (not at middle school), but the differences were very small compared with other countries (Beaton et al. 1996a,b; Martin et al. 1997, 1998; and Mullis et al. 1997.)

Ethnic Differences in Performance. Comparisons of performance by racial/ethnic group are presented in figures 5-6 and 5-7. In science, more white, black, and Hispanic 9-year-olds reached benchmark (Level 200) in 1996 than in 1977. The change was particularly noteworthy for black students, who showed a 25 percentage-point increase from the initial assessment (27 percent) to the most recent one (52 percent). By comparison, the percentage of Hispanic students increased from 42 percent to 58 percent and the percentage of white students increased from 77 percent to 84 percent. As these numbers show, white students started off well ahead of black and Hispanic students in 1977 and remained well ahead through 1996. The disparity between white and black students at the 200 benchmark declined from 50 percentage points in 1977 to 32 percentage points in 1996. Changes in the white-Hispanic

Figure 5-6.
Trends in the percentage of students at or above benchmark levels of NAEP science performance, by age and race/ethnicity: 1977–96



NAEP = National Assessment of Educational Progress

SOURCE: National Center for Education Statistics (NCES). 1997. *NAEP 1996 Trends in Academic Progress.* NCES 97-985. Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

See appendix tables 5-6, 5-7, and 5-8.

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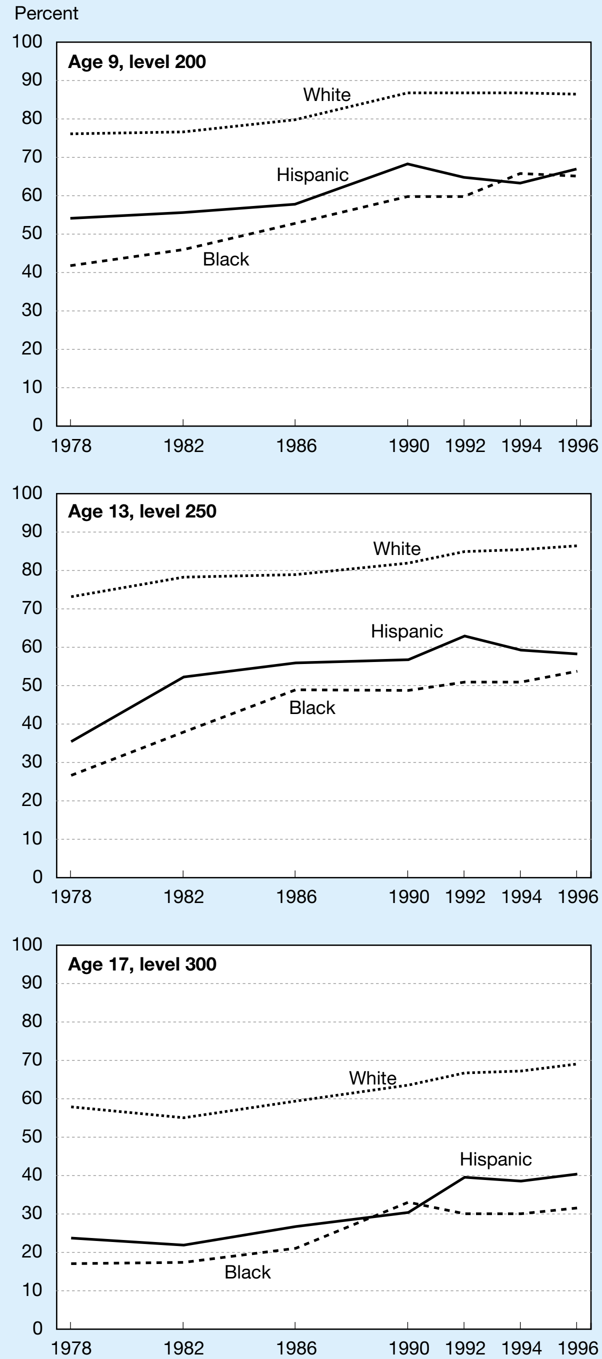
Figure 5-7.
Trends in the percentage of students at or above benchmark levels of NAEP mathematics performance, by age and race/ethnicity: 1978–96



NAEP = National Assessment of Educational Progress

SOURCE: National Center for Education Statistics (NCES). 1997. *NAEP 1996 Trends in Academic Progress.* NCES 97-985. Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

See appendix tables 5-9, 5-10, and 5-11.

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performance differences were more modest over that time period. The initial difference was 35 percentage points, while the difference in 1996 was 26 percentage points.

More 13-year-olds in all three racial/ethnic groups reached the benchmark (Level 250) on the science assessment in 1996 than in 1977. White students demonstrated a 12 percentage-point increase in reaching benchmark performance, black students a 10-point increase, and Hispanic students a 13 percentage-point increase. Again, white students started off well ahead of black and Hispanic students and this comparison continued through the years. Among 13-year-olds, performance differences between white-black and white-Hispanic groups did not narrow significantly over time.

Greater percentages of white and black 17-year-olds reached Level 300 in science in 1996 than in 1977, increasing by 11 and 10 percentage points, respectively. The proportion of 17-year-old Hispanic students achieving Level 300 increased by 5 percentage points. The upward trend in all three groups was statistically significant. As is the established pattern, more white students than black and Hispanic students attained Level 300 throughout the assessments.

In mathematics, significantly more 9-year-olds reached Level 200 in 1996 in all three racial/ethnic groups than in 1978. Black students showed the greatest improvement (from 42 to 65 percent) in reaching benchmark performance levels. White and Hispanic students showed increases of 11 and 13 percentage points, respectively. The disparity between white and black students but not that between white and Hispanic students decreased over this interval. The difference between white and black students reaching benchmark performance was 34 percentage points in 1978 and 22 percentage points in 1996.

There were improvements in the percentage of white, black, and Hispanic 13-year-old students reaching Level 250 between the first and most recent mathematics assessment. The differences between white and Hispanic students decreased from 37 percentage points in 1978 to 28 percentage points in 1996. The difference in performance between black and white students also decreased, from 44 to 32 percentage points. Major differences remained between the groups in 1996. About 86 percent of white students, 54 percent of black students, and 58 percent of Hispanic students scored at the benchmark level.

White, black, and Hispanic 17-year-olds functioned at significantly higher levels of mathematics performance in 1996 than in 1978. The increase for white students was from 58 percent to 69 percent; for black students, from 17 percent to 31 percent; and for Hispanic students, from 23 percent to 40 percent. As these numbers also reveal, white students held the edge from the first to the most recent assessment and no significant reduction in performance differences occurred from the first to the most recent assessment.[2]

[2]Appendix table 5-12 presents comparable trends information based on average scale scores.

Summary of NAEP Performance

Science and mathematics achievement in the early and middle grades have improved during the years in which trends assessments were conducted. Compared to 1977/78 performance levels, more 9- and 13-year-olds demonstrated understanding of simple scientific principles and could understand and apply general information from life and physical sciences in 1996. Mathematics achievement for these age groups also has improved since 1978. More 9- and 13-year-old students could perform two-digit addition and subtraction in 1996 than in 1978. More students also had command of the four basic arithmetic operations and could solve simple mathematical problems.

More 17-year-olds showed evidence of detailed scientific knowledge and evaluation of scientific procedures in 1996 than in 1977. More students also demonstrated mastery of one-step problems in 1996—a small but significant improvement. More 17-year-olds showed that they could compute with decimals and fractions and use moderately complex reasoning in 1996.

There also are negative aspects to these findings. Many 9-year-olds lack a good cognitive foundation on which to build future knowledge and understanding. About 70 percent of these students could not compute using whole numbers or could not solve one-step problems. More than 40 percent of 13-year-olds could not apply information from the life and physical sciences. About half of 17-year-olds could not evaluate scientific procedures and 40 percent were deficient in computation or in the use of moderately complex reasoning. Taken as a whole, the data suggest that, while definite improvements in achievement have occurred, the situation remains disappointing for black and Hispanic students. On average, black and Hispanic groups continued to score well below white students, even where there was some success in narrowing the gaps.

U.S. Achievement in an International Context

International assessments provide another perspective on U.S. achievement. The most recent study, the Third International Mathematics and Science Study (TIMSS), conducted in 1995, included assessment of fourth and eighth grade students as well as students in their final year of secondary school. The study included several components: the assessments, analyses of curricula for various countries, and an observational-video study of mathematics instruction in eighth grade classes in Germany, Japan, and the United States.

Achievement of Fourth and Eighth Grade American Students

TIMSS results for fourth and eighth grade students have been widely reported, including in the previous volume of S&E Indicators (NSB 1998). Often observers have expressed grave concern about the implications of TIMSS results for the science and mathematics education being provided to the

Nation's students. The National Science Board reports TIMSS' results in *Preparing Our Children: Math and Science Education in the National Interest* (NSB 1999). Among other issues critical to precollege education, the report recommended collaborative review of instructional materials by mathematics and scientists employed in knowledge-based industries, parents, and others. The report also recommended the partnership of teacher education instruction with relevant state and local agencies to create constructive alignment of teacher preparation, certification, and hiring practices and policies.

TIMSS findings are outlined here in only general terms. U.S. fourth grade students performed at competitive levels in both science and mathematics. In science, they scored well above the 26-country international average overall as well as in all content areas assessed—earth sciences, life sciences, physical sciences, and environmental issues/nature of science. Only students in South Korea scored at a higher level overall. (See figure 5-8, and appendix table 5-13.) The fourth grade assessment in mathematics covered topics in whole numbers; fractions and proportionality; measurement, estimation, and number sense; data representation, analysis, and probability; geometry; and patterns, functions, and relations. Fourth grade students also did well on this assessment, scoring above the international average and performing comparatively well in all content areas except measurement (NCES 1997c). (See figure 5-8 and appendix table 5-14.)

As with grade 4 students, the TIMSS science assessment taken by eighth grade students covered earth and life sciences and environmental issues, but also included content in physics and chemistry. With a mean score of 534 in science, grade 8 U.S. students scored above the 41-country international average of 516. (See figure 5-9.) U.S. students performed about at the international average in chemistry and physics, and above average on life sciences, earth sciences, and environmental issues (NCES 1997c). (See appendix table 5-15.)

Figure 5-9 shows that mathematics was the weaker area of eighth grade achievement. The assessment covered fractions and number sense; geometry; algebra; data representation and probability; measurement; and proportionality. Overall, eighth grade U.S. students performed below the 41-country international average and about at the international average in algebra, data representation, and fractions and number sense. Performance on geometry, measurement, and proportionality were below the international average. (See figure 5-9 and appendix table 5-16.)

Achievement of Students in the Final Year of Secondary School

The performance of students in the final year of secondary school can be considered a measure of what students have learned over the course of their years in school. Assessments were conducted in 21 countries to examine performance on the general knowledge of mathematics and science expected of all students, as well as more specialized content taught only in advanced courses.

Achievement on General Knowledge Assessments

The TIMSS general knowledge assessments were taken by all students, including those not taking advanced mathematics and science courses. The assessment covered earth sciences/life sciences and physical sciences topics covered in grade 9 in many other countries but not until grade 11 in U.S. schools. On the general science knowledge assessment, U.S. students scored 20 points below the 21-country international average, comparable to the performance of 7 other nations but below the performance of 11 other nations participating in the assessment. Only 2 of the 21 countries, Cyprus and South Africa, performed at a significantly lower level than the United States. (See figure 5-10.) It is noteworthy, however, that the countries performing similarly to the United States included Germany, Russia, France, the Czech Republic, Italy, and Hungary.

The general mathematics assessment covered topics most comparable to seventh grade material internationally and ninth grade material in the United States. Again, U.S. students scored below the international average, outperformed by 14 countries but scoring similarly to Italy, the Russian Federation, Lithuania, and the Czech Republic. As on the general science assessment, only Cyprus and South Africa performed more poorly. (See figure 5-10.) These results suggest that mathematics and science students in the United States appear to be losing ground to students in many other countries as they progress from elementary to middle to secondary school.

Achievement of Advanced Students

The TIMSS physics assessment was administered to students in countries who were taking advanced science courses and by U.S. students who were taking or had taken physics I and II, advanced physics, or advanced placement (AP) physics. The assessment covered mechanics and electricity/magnetism as well as particle, quantum, and other areas of modern physics.

Compared to their counterparts in other countries, U.S. students performed below the international average of 16 countries on the physics assessment. The mean achievement scores of the U.S. (423) and Austria (435) were at the bottom of the international comparison (average = 501). Students in 14 other countries scored significantly higher than the United States and no country achieved at a lower level. Advanced Placement physics students in the U.S. (not shown) scored 474 on the assessment, while 6 countries scored higher (scores ranging from 518 to 581). Only Austria performed at a significantly lower level, with a score of 435 (NCES 1998a).

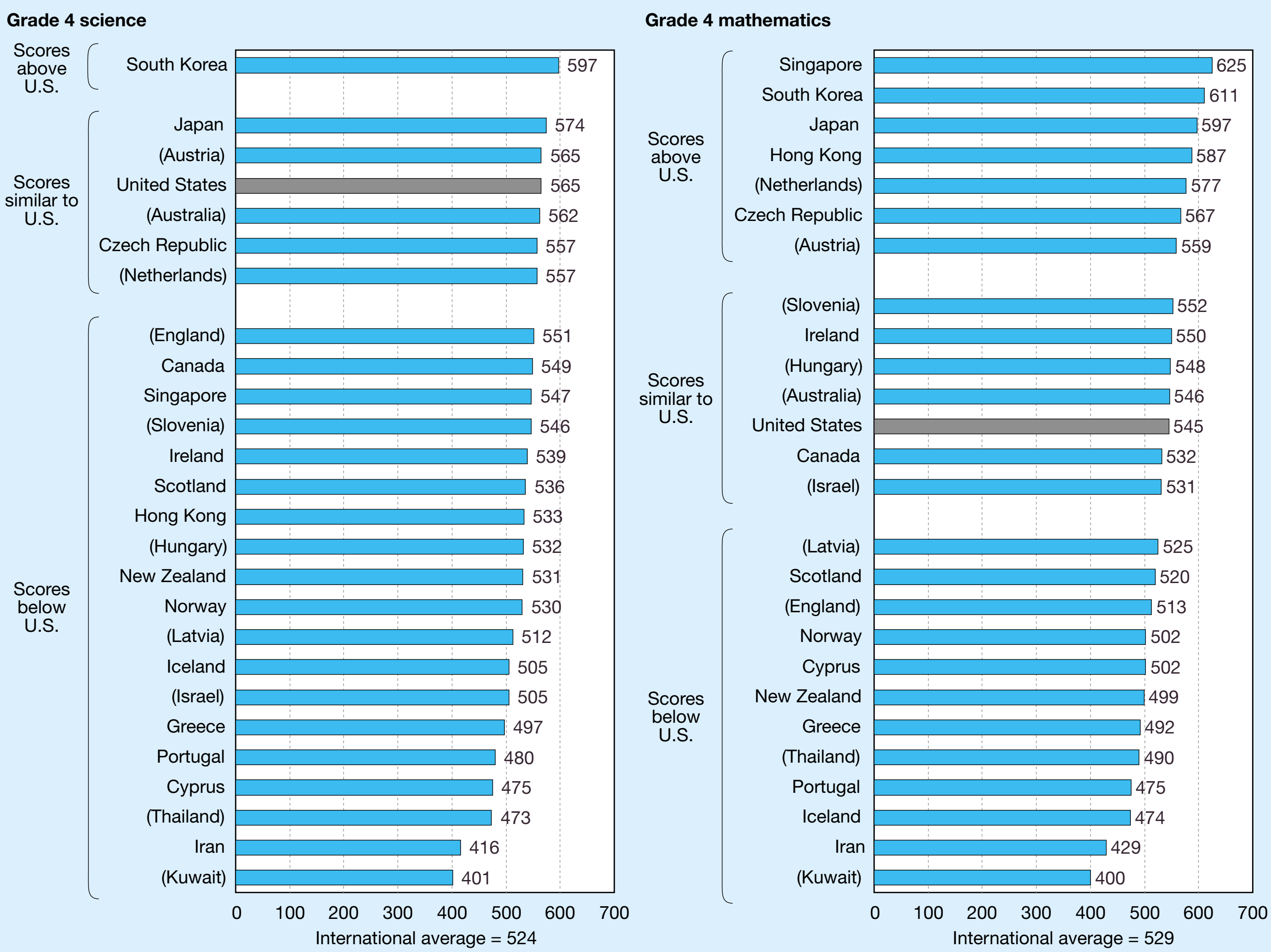
The advanced mathematics assessment was administered to students in other countries who were taking advanced mathematics courses and by U.S. students who were taking or had taken calculus, pre-calculus, or AP calculus. One-quarter of the items tested calculus knowledge. Other topics included numbers, equations and functions, validation and structure, probability and statistics, and geometry.

The international average on the advanced mathematics assessment was 501. American students, with a score of 442, were outperformed by students in 11 nations, whose average scores ranged from 475 to 557. No nation performed significantly below the United States, while Italy, the Czech Republic, Germany, and Austria performed at about the same level. (See figure 5-11.) U.S. students who had taken AP calculus (not shown) had an average score of 513, exceeded only by students in France. Five nations scored significantly lower than the AP calculus students in the United States.

Performance of the Highest Achievers

Contrasting the performance of the "best and brightest" American students with the best in other nations provides a comparison of the students in each country who are most likely to move through the educational pipeline to careers in science, mathematics, and engineering. One widely comparative index is the percentage of students in each country scoring within the top 10 percent of the students in all participating countries at all grade levels in international distribution. Data on this measure were reported only for grade 4 and grade 8 students.

Figure 5-8.
Average scale score on grade 4 TIMSS science and mathematics assessments relative to U.S. averages, by country: 1994–95



TIMSS = Third International Mathematics and Science Study

NOTE: Nations not meeting international guidelines are shown in parentheses.

SOURCES: Martin, M., I. Mullis, A. Beaton, E. Gonzalez, T. Smith, and D. Kelly. 1997. *Science Achievement in the Primary School Years: IEA's Third International Mathematics and Science Study (TIMSS).* Chestnut Hill, MA: Boston College, TIMSS International Study Center; Mullis, I., M. Martin, A. Beaton, E. Gonzalez, D. Kelly, and T. Smith. 1997. *Mathematics Achievement in the Primary School Years: IEA's Third International Mathematics and Science Study (TIMSS).* Chestnut Hill, MA: Boston College, TIMSS International Study Center.

See appendix tables 5-13 and 5-14.

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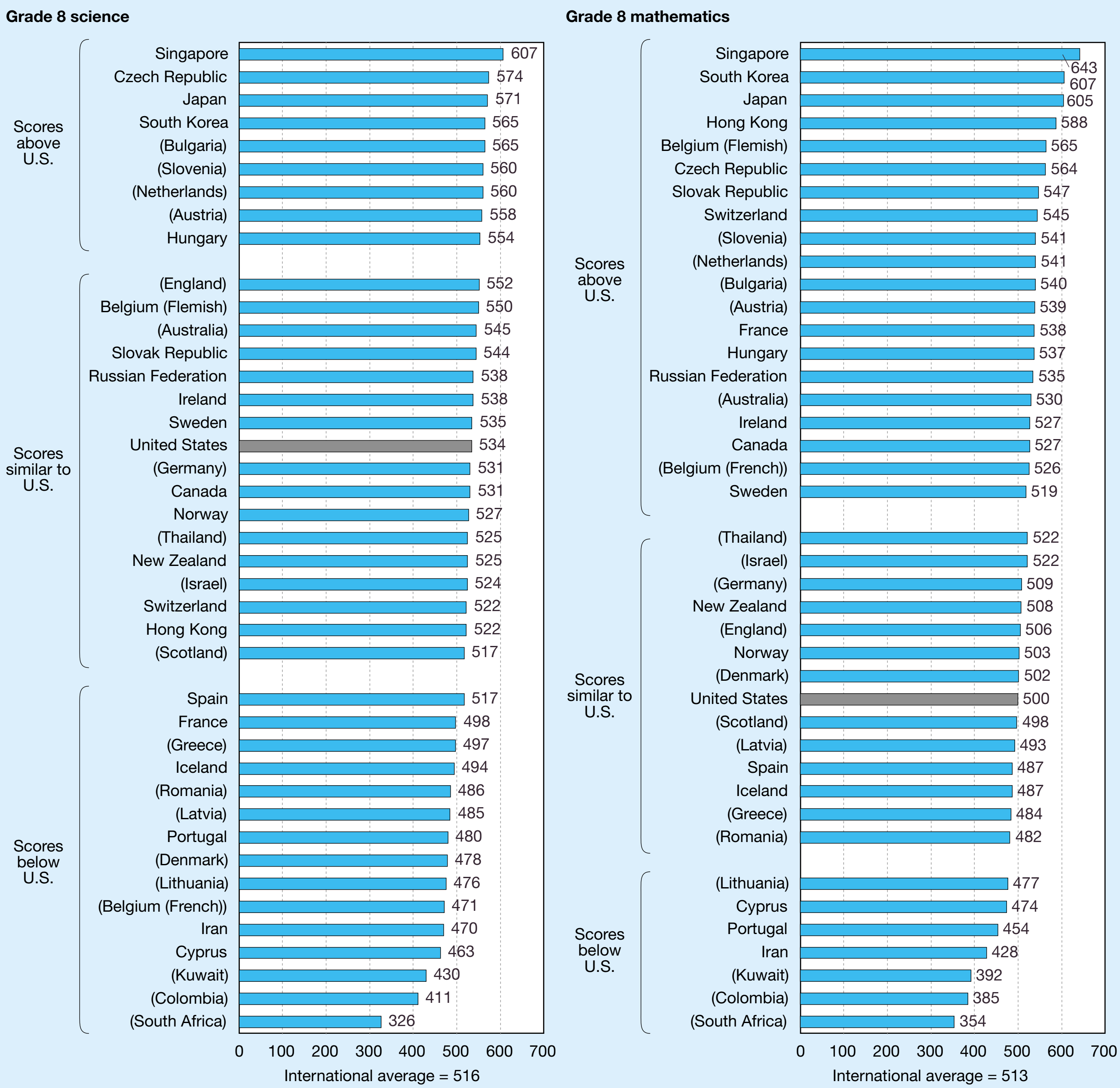
Figure 5-9.
Average scale score on TIMSS science and mathematics assessments for students in grade 8, by country: 1994–95



TIMSS = Third International Mathematics and Science Study

NOTE: Nations not meeting international guidelines are shown in parentheses.

SOURCES: Martin, M., I. Mullis, A. Beaton, E. Gonzalez, T. Smith, and D. Kelly. 1997. *Science Achievement in the Primary School Years: IEA's Third International Mathematics and Science Study (TIMSS).* Chestnut Hill, MA: Boston College, TIMSS International Study Center; Mullis, I., M. Martin, A. Beaton, E. Gonzalez, D. Kelly, and T. Smith. 1997. *Mathematics Achievement in the Primary School Years: IEA's Third International Mathematics and Science Study (TIMSS).* Chestnut Hill, MA: Boston College, TIMSS International Study Center.

See appendix tables 5-15 and 5-16.

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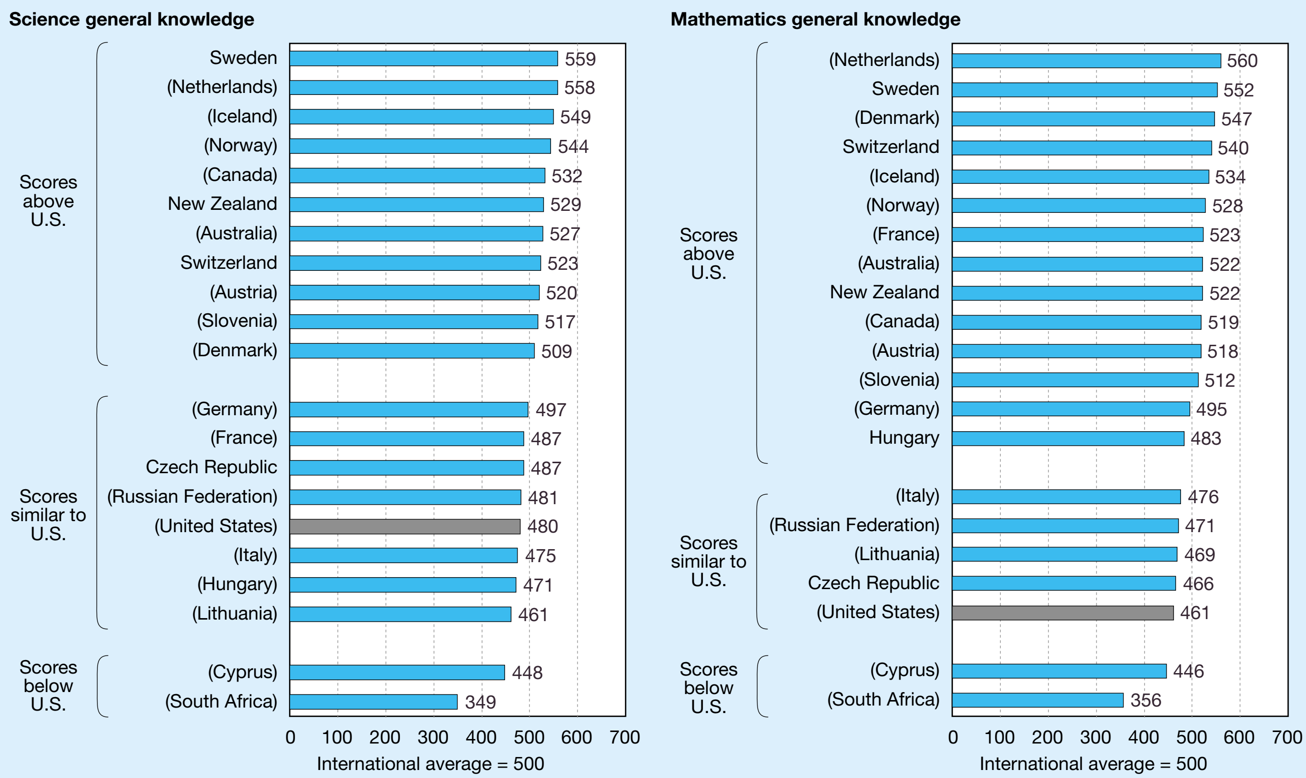
Figure 5-10.
Mean scale score on TIMSS general knowledge assessments in mathematics and science for students in their final year of secondary school: 1994–95



TIMSS = Third International Mathematics and Science Study

NOTE: Nations not meeting international guidelines are shown in parentheses.

SOURCE: Mullis, I., M. Martin, A. Beaton, E. Gonzalez, D. Kelly, and T. Smith. 1998. *Mathematics and Science Achievement in the Final Year of Secondary School: IEA's Third International Mathematics Study.* Chestnut Hill, MA: Boston College, TIMSS International Study Center.

See appendix table 5-17.

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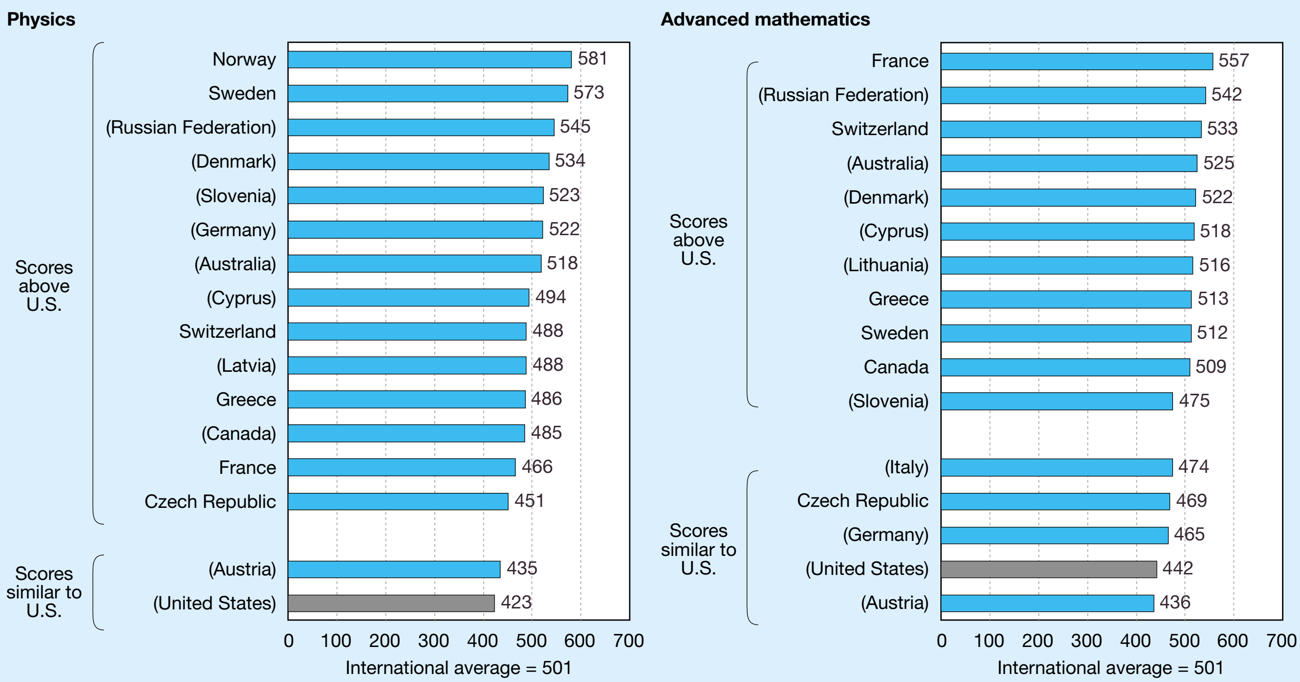
Relatively speaking, grade 4 students were the most internationally competitive of U.S. students. Sixteen percent of fourth grade U.S. students scored in the top 10 percent in science and 9 percent did so in mathematics. Thirteen percent of grade 8 students performed as well as the top 10 percent of TIMSS participants, but only 5 percent reached that benchmark in mathematics. (See appendix table 5-19.) Students in some U.S. schools are performing well above the national average and well above students from many other countries; schools in the First in the World Consortium are in this select group. (See sidebar, "First in the World Consortium Near the Top.")

Performance of Students from the G-7 Nations

Of perhaps particular interest to policymakers is how well the U.S. students performed relative to the country's major trading partners, the six additional members of the "group of 7" (G-7): Canada, France, Germany, Italy, Japan, and the United Kingdom (England, Scotland, Northern Ireland, and Wales). Because not all countries participated in each of the assessments, the potential comparisons are limited. A comparison of mean scale scores of the G-7 countries shows that on the science assessment the scores of fourth graders in the United States did not differ significantly from those in Japan and were higher than those of Canada, England, and Scotland. In 4th grade mathematics, Japanese students achieved a higher level than the United States, while the United States did not differ significantly from Canada and was higher than Scotland and England (NCES 1998b). (See figure 5-8.) On the grade 8 science assessment, only Japan outscored the United States, whose performance was comparable to that of England, Scotland, Canada, and Germany but better than France. In mathematics, the achievement of U.S. students was surpassed by that of students in Japan, France, and Canada, while U.S. students performed similarly to eighth grade students in Germany, England, and Scotland (Beaton et al. 1996a, b). (See figure 5-9.)

Figure 5-11.
Average scale score on TIMSS physics and advanced mathematics assessment for students in their final year of secondary school: 1994–95



TIMSS = Third International Mathematics and Science Study

NOTE: Nations not meeting international guidelines are shown in parentheses.

SOURCE: Mullis, I., M. Martin, A. Beaton, E. Gonzalez, D. Kelly, and T. Smith. 1998. *Mathematics and Science Achievement in the Final Year of Secondary School: IEA's Third International Mathematics Study.* Chestnut Hill, MA: Boston College, TIMSS International Study Center.

See appendix table 5-18.

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Summary of TIMSS Findings

In brief, the findings of the TIMSS assessments showed that U.S. students have higher achievement in science than in mathematics; that students in the primary grades demonstrated the strongest performance, especially in science; that students in grade 8 showed weaker performance; and that those in grade 12 showed weaker performance still, relative to their cohorts in other countries.

Science and Mathematics Coursework

In 1980, before *A Nation at Risk* motivated states to increase graduation requirements, 37 states had minimal graduation requirements on the books. By 1990, 43 states had specified the courses and number of credits needed for graduation. The National Education Commission on Time and Learning reports several studies showing that new requirements did not appreciably change the number of Carnegie units students were required to take. By one estimate, the average number of credits required for graduation in 1980 was 17. In 1990, the average was 20 credits, representing less than 10 percent difference over the 10 years (NECTL 1994).

The NECTL cites research indicating positive effects of strengthened graduation requirements. Schools offered more academic courses, particularly in mathematics and science, and more students, including minority and at-risk students, actually enrolled in the courses. The 1994 High School Transcript Study (HSTS), which examined the records of more than 25,000 graduating seniors, confirms that outcome. Students took more advanced science and mathematics courses in 1996 than did students who graduated in the late 1970s (NCES 1998e). In 1994, almost all graduating seniors (93 percent) had taken biology and more than one-half (56 percent) took chemistry. In comparison, 77 percent of 1982 seniors had completed biology and 31 percent had completed chemistry. In the class of 1994, almost one-quarter of graduates had completed physics, compared to 14 percent of 1982 graduates. (See figure 5-12 and text table 5-5.) Appendix table 5-21 provides participation rates for advanced placement and other science courses.

In 1994, more graduating students had taken advanced mathematics courses than did their counterparts in prior years. In 1994, 58 percent of students took algebra 2, compared to 36 percent in 1982. The 1994 participation rates for geometry and calculus were 70 percent and 9 percent, respectively.

First in the World Consortium Near the Top

The First in the World Consortium was started by a group of North Shore school superintendents in Illinois to work collectively on specific administrative issues. One of their last meetings focused on Goals 2000 (legislation that called for national goals and world-class standards). From this discussion came a commitment to create a regional consortium of districts driven by the need to pursue a world-class education for their students.

Schools in the First in the World Consortium showed quite strong performance on all TIMSS assessments. They scored well above the general population of U.S. students and above the international mean at all three grades and on both the general knowledge and advanced exams in mathematics and science at the end of secondary school.

Highest scoring country

Grade	Mathematics		Science	
4	Singapore	625	South Korea	597
8	Singapore	643	Singapore	607
12 Literacy	Netherlands	560	Sweden	559
12 Advanced ...	France	557	Norway	581

SOURCE: IEA Third International Mathematics and Science Study, 1994-95.

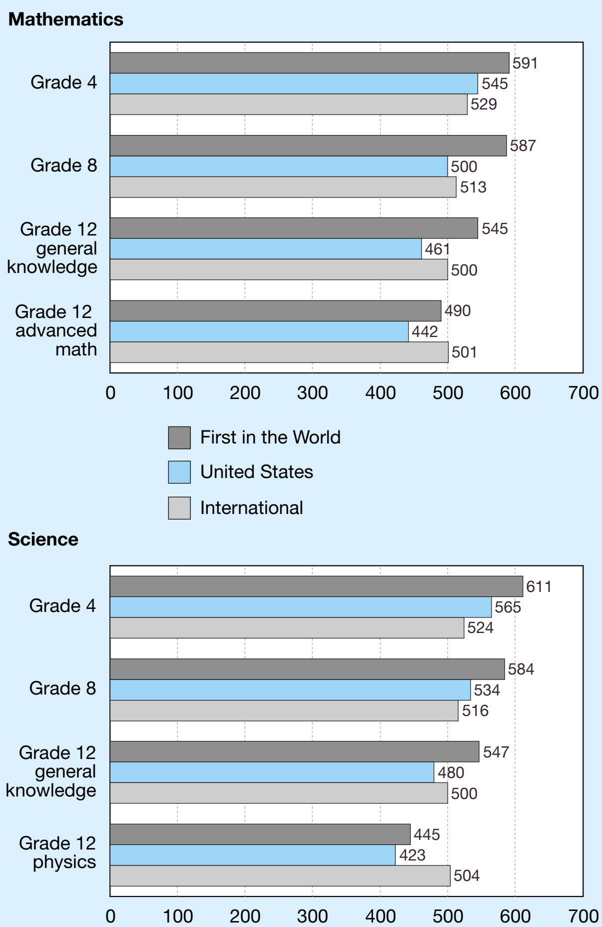
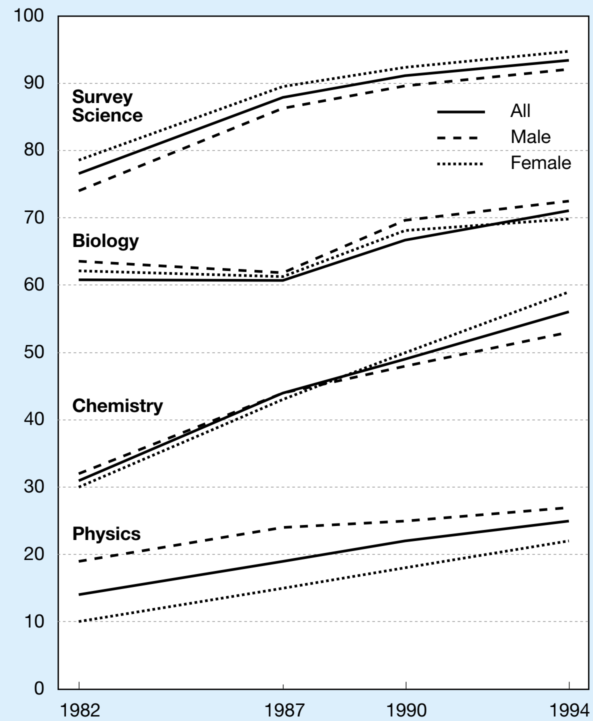


Figure 5-12.
Percentage of high school graduates taking science courses, by gender: 1982–94



SOURCE: National Center for Education Statistics (NCES). 1998. *The 1994 High School Transcript Study: Comparative Data on Credits Earned and Demographics for 1994, 1990, 1987, and 1982 High School Graduates.* Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

See appendix tables 5-21 & 22.

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Corresponding figures for 1982 were 46 percent in geometry and 5 percent in calculus. From 1982 to 1994, there was a corresponding decrease in lower-level courses such as general mathematics, which dropped from 30 percent to 16 percent for 1994 over that period. (See figure 5-13 and text table 5-6.) Refer to appendix table 5-22 for information on other mathematics courses, including AP calculus (NCES 1998e).

Gender Differences in Course Participation. The association between courses taken in high school and later educational outcomes has been established for some time (Sells 1978 and Smith 1996). Given the lower representation of women throughout the science, mathematics, and engineering pipeline, there has long been an interest in tracking gender differences in the patterns of advanced science and mathematics courses taken. Data from the recent transcript study show that, in 1982, approximately 79 percent of female graduates completed biology, 30 percent completed chemistry, and 10 percent completed physics (NCES 1998e). The corresponding numbers in 1994 were 95 percent, 59 percent, and 22 percent, respectively. For males, 74 percent completed biology in 1982 and 92 percent in 1994, 32 percent

Text table 5-5.
Percentage of high school graduates earning credits in science courses, by gender and race/ethnicity: 1982 and 1994

Year of graduation and characteristic	Survey science	Biology	Chemistry	Physics
1982				
All	62	77	31	14
Male	64	74	32	19
Female	61	79	30	10
White	62	79	34	17
Asian/Pacific Islander	41	84	53	35
Black	68	73	22	8
Hispanic	63	69	16	6
American Indian/Alaskan Native	58	67	26	8
1994				
All	71	93	56	25
Male	73	92	53	27
Female	70	95	59	22
White	72	94	58	26
Asian/Pacific Islander	62	92	69	44
Black	72	92	44	15
Hispanic	70	94	46	16
American Indian/Alaskan Native	79	92	41	10

SOURCE: National Center for Education Statistics (NCES). 1998. *The 1994 High School Transcript Study: Comparative Data on Credits Earned and Demographics for 1994, 1990, 1987, and 1982 High School Graduates*. Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

See appendix tables 5-21 and 5-23. *Science & Engineering Indicators – 2000*

completed chemistry in 1982 and 53 percent in 1994, and 19 percent completed physics in 1982 and 27 percent in 1994. For both male and female graduates, the biggest percentage-point increases were in physics. In all three of these advanced science courses, differences between male and female participation decreased from 1982 to 1994. (See figure 5-12, text table 5-5, and appendix table 5-21.)

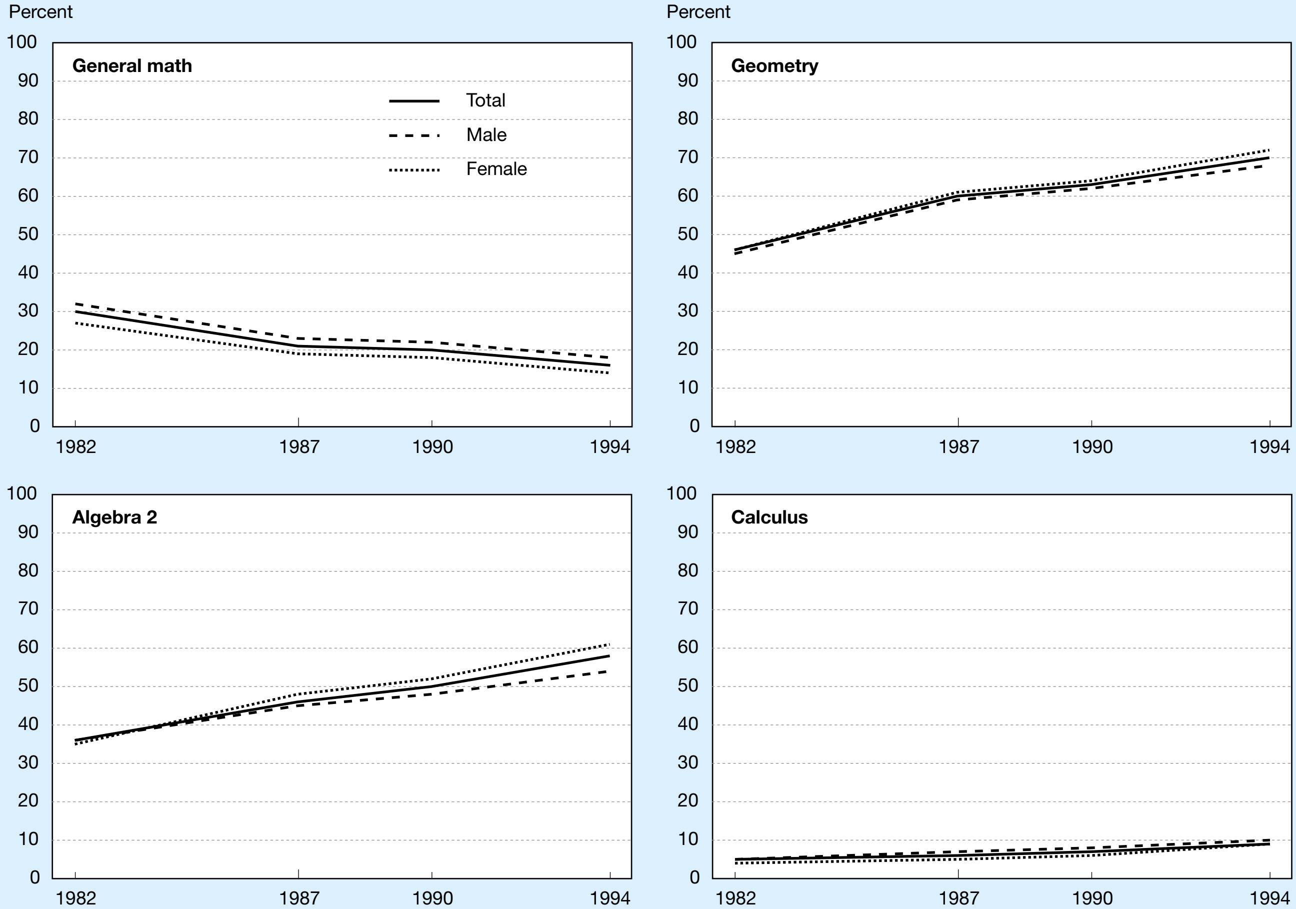
Both male and female students took more advanced mathematics courses in 1994 than in 1982. For both genders, completion rates for algebra 2 and geometry increased 19 to 26 percentage points. The percentages of male and female students completing calculus doubled over that period, reaching almost 10 percent for both genders in 1994. In 1994, approximately 54 percent of male students and 61 percent of female students completed algebra 2 and 68 percent of males and 72 percent of females completed geometry. (See figure 5-13, text table 5-6, and appendix table 5-22.)

Ethnic Differences in Course Participation. Educators have also tracked course taking patterns by ethnic group (NCES 1998e). Students from racial and ethnic groups that are typically underrepresented in science made substantial gains in their proportions taking advanced science courses. More than 90 percent of black, Hispanic, and American Indian/Alaskan Native students now complete biology. In chemistry, the proportion of black students completing chemistry doubled between 1982 and 1994 (from 22 to 44 percent), the completion rate for Hispanic students nearly tripled (from 16 to 46 percent), and for American Indian/Alaskan Natives, the proportion increased by more than one-half (from 26 to 41 percent). All categories made progress in physics course taking between 1982 and 1994, although the proportions of students from black, Hispanic, and American Indian/Alaskan Native groups remained 16 percent or lower in 1994. Corresponding 1994 rates for white and Asian/Pacific Islander students were 26 percent and 44 percent, respectively. (See figure 5-14 and text table 5-5.)

Figure 5-15, which shows the pattern of higher-level mathematics courses completed by ethnic group, indicates that more high school seniors in all ethnic groups completed advanced mathematics courses in 1994 than in 1982. Increases for white and Asian/Pacific Islander students are evident in geometry, algebra 2, and calculus. Increases were also apparent for students in racial/ethnic groups that typically are underrepresented in mathematics and the sciences.

For American Indian/Alaskan Natives, the course completion rate for algebra 2 increased from 19 percent to 42 percent; for geometry the rate moved from 34 to 60 percent. The proportion of black students completing algebra 2 increased from 24 percent to 44 percent; for geometry, the increase was from 29 to 58 percent. The geometry completion rate of Hispanics increased from 26 to 69 percent and in algebra 2 from 20 to 50 percent. In 1994, about one-quarter of Asian/Pacific Islander students completed calculus compared with about 10 percent of whites, 6 percent of Hispanics, and 4 percent each of black

Figure 5-13.
Percentage of high school graduates earning credits in selected mathematics courses, by gender: 1982–94



SOURCE: National Center for Education Statistics (NCES). 1998. *The 1994 High School Transcript Study: Comparative Data on Credits Earned and Demographics for 1994, 1990, 1987, and 1982 High School Graduates.* Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

See appendix table 5-22.

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and American Indian/Alaskan Native students. In 1994, the familiar pattern of course completions held. In 1994, as in 1982, more white and Asian/Pacific Islander students completed advanced mathematics courses. (See figure 5-15.)

Research is mixed as to whether the positive effects of stronger requirements were counterbalanced by negative effects. For example, minority and at-risk students failed more courses than before mandates were put into practice (NECTL 1994). Opinions differ on the quality of the added courses, especially those taken by low achieving students. There was particular concern about the quality of new courses designed for low achievers, who, under the traditional pipeline, would have taken general or basic mathematics. Some research suggests that most of the new courses mandated by increased graduation requirements were remedial, low level, or basic rather than advanced (Porter, Smithson, and Osthoff 1994).

Other recent studies have come to a different conclusion. Studying 18 high schools in 12 districts in 6 states, Porter, Smithson, and Osthoff (1994) found no evidence that the newer courses were diluted. Gamoran's (1996) research replicated this finding and also reported that bridging courses achieved some success. Bridging courses helped ease the transition of lower achieving students to college-preparatory courses. The question has great relevance to education policy as schools in Boston require all ninth grade students to take algebra, and schools in New York City require all students to take academic mathematics and science courses during their first two years of high school. Gamoran's research also showed that students who took bridging courses were not as academically successful as students taking college-preparatory mathematics; however, their success was greater than that of students who had taken general mathematics courses (Gamoran 1996).

On balance it appears too early to draw general conclusions about the quality of these new courses. The studies cited here—both confirming and disconfirming that the

Text table 5-6.
Percentage of high school graduates earning credits in mathematics courses, by gender and race/ethnicity: 1982 and 1994

Year of graduation and characteristic	Mathematics course: General Math	Algebra 2	Geometry	Calculus
1982				
All	30	36	46	5
Male	32	36	45	5
Female	27	35	46	4
White	25	40	51	5
Asian/Pacific Islander	17	56	65	13
Black	47	24	29	1
Hispanic	43	20	26	2
American Indian/Alaskan Native	41	19	34	4
1994				
All	16	58	70	9
Male	18	54	68	10
Female	14	61	72	9
White	15	62	72	10
Asian/Pacific Islander	18	66	76	24
Black	27	44	58	4
Hispanic	16	50	69	6
American Indian/Alaskan Native	19	42	60	4

SOURCE: National Center for Education Statistics (NCES). 1998. *The 1994 High School Transcript Study: Comparative Data on Credits Earned and Demographics for 1994, 1990, 1987, and 1982 High School Graduates*. Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

See appendix tables 5-22 and 5-24.

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courses were diluted—were conducted in only a handful of states and school districts, and in a handful of courses. Moreover, the earlier studies appear to have been conducted not long after the mandates were enforced. Thus, there may have been little opportunity for revisions and improvement.

Curriculum and Instruction

Challenging instruction is at the core of new educational standards. Both the science and mathematics standards present compelling visions of instruction, although neither provides an exact blueprint. Measuring the extent to which this vision is becoming a reality is difficult because available methodologies cannot measure quality directly. Instead, educational researchers have relied most often on indicators of the amount of time students spend studying a subject (classwork and homework) and the content of lessons, as well as the use of instructional resources such as textbooks and technology. Lacking, until quite recently, were indicators that better reflect instruction as a process.

Instructional Time

The question of whether U.S. students spend enough time in school or receiving instruction has persisted for many years and research results on this issue are mixed. Research by Stigler and Stevenson (1991) showed that U.S. students spend fewer hours in school than Japanese students and that U.S. schools allocate less time to core instruction than do other industrialized nations. For example, core academic time in U.S. schools was estimated at 1,460 hours during the four years of high school compared to 3,170 hours in Japan. The National Educational Commission on Time and Learning reported in 1994 that, at the time of the Commission's study, only 10 states specified the number of hours to be spent in academic subjects at various grades. Only 8 others provided recommendations regarding academic time. Based on these and other findings, the Commission concluded that "[T]ime is the missing element in the debate about the need for higher academic standards.... We have been asking the impossible of our students—that they learn as much as their foreign peers while spending only half as much time in core academic studies" (NECTL 1994).

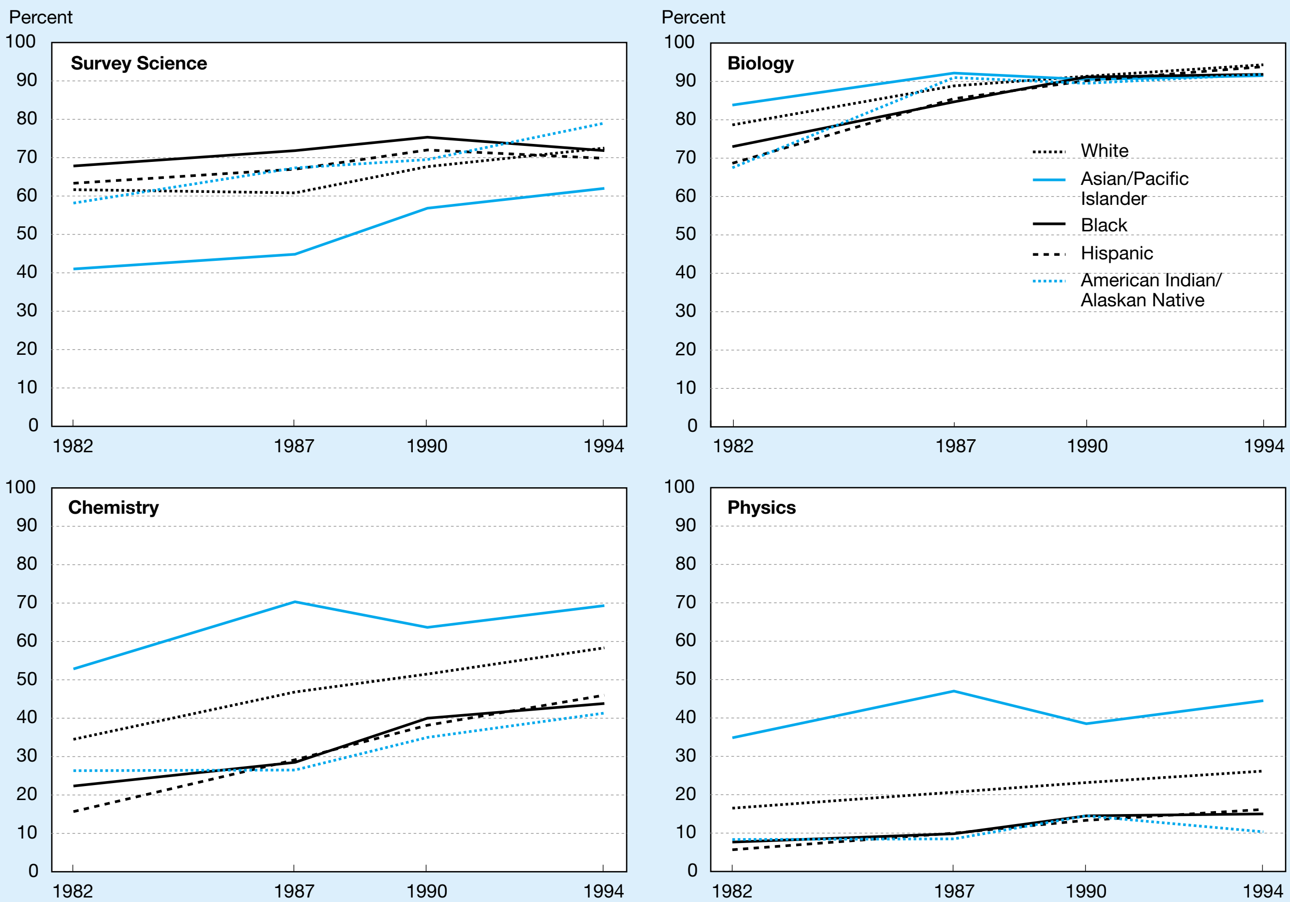
TIMSS data suggested that this may not have been true of mathematics and science in 1995. Students in the United States receive at least as much classroom time in mathematics and science instruction as students in other nations—close to 140 hours per year in mathematics and 140 hours per year in science. Students in Germany, Japan, and the United States spent about the same time on a typical homework assignment, but U.S. students were assigned homework more often, thus increasing total time spent studying in the two subjects (Beaton et al. 1996b; NCES 1996a, 1997b, and 1997c). (See figure 5-16.) Certain caveats are necessary in interpreting results on instructional time. First, in other nations—particularly Japan—students participate in extracurricular mathematics and science activities in after school clubs. Second, disruptions for announcements, special events, and discipline problems in U.S. classrooms considerably reduce the amount of allocated time actually spent on instructional activities (Stigler et al. 1999).

Content: Curriculum and Textbooks

Analyses conducted in conjunction with TIMSS (Schmidt, McKnight, and Raizen 1997) documented that curriculum guides in the United States include more topics than is the international norm. Most other countries focus on a limited number of topics, and each topic is generally completed before a new one is introduced. U.S. curricula, by contrast, follow a "spiral" approach: topics are introduced in an elemental form in the early grades, then elaborated and extended in subsequent grades. One result of this is that U.S. curricula are quite repetitive—the same topic appears and reappears at several different grades. Another result is that topics are not presented in any great depth, giving U.S. curricula the appearance of being unfocused and shallow in appearance.

The Schmidt et al. (1997) study also suggested that U.S. curricula make fewer intellectual demands on students, delaying until later grades topics that are covered much earlier in other countries. U.S. mathematics curricula also were judged to be less advanced, less challenging, and out of step with curricula in other countries. The middle-school curriculum in most TIMSS countries, for example, covers topics in algebra, geometry, physics, and chemistry. Meanwhile, the grade 8 curriculum in U.S. schools is closer to what is taught in grade 7 in other countries and includes a fair amount of arithmetic. Science curricula, by comparison, are closer to international norms in content and in the sequence of topics.

Figure 5-14.
Percentage of high school graduates earning credits in selected science courses, by race/ethnicity: 1982–94



SOURCE: National Center for Education Statistics (NCES). 1998. *The 1994 High School Transcript Study: Comparative Data on Credits Earned and Demographics for 1994, 1990, 1987, and 1982 High School Graduates.* Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

See appendix table 5-23.

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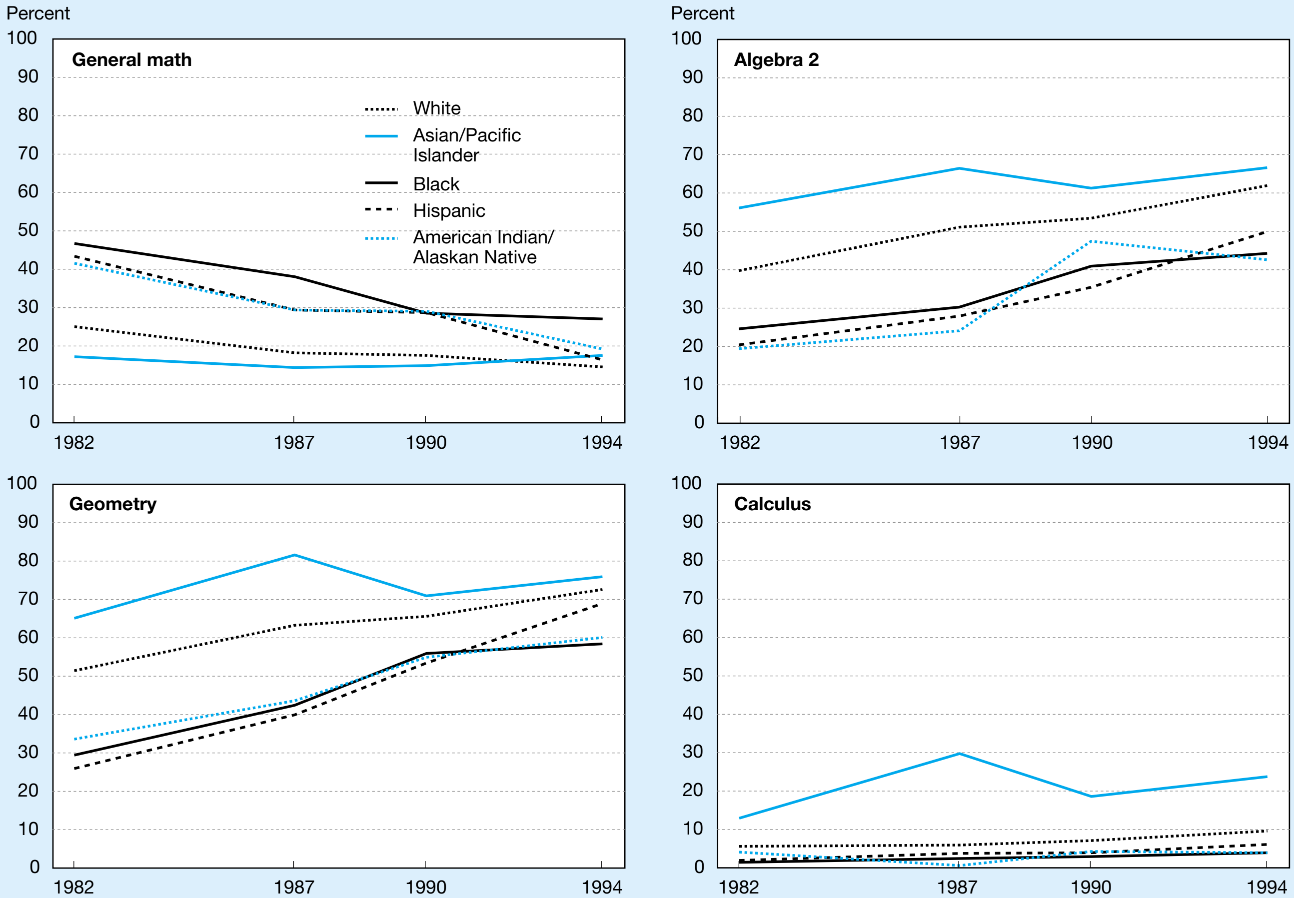
Figure 5-15.
Percentage of high school graduates earning credits in mathematics courses, by race/ethnicity: 1982–94



SOURCE: National Center for Education Statistics (NCES). 1998. *The 1994 High School Transcript Study: Comparative Data on Credits Earned and Demographics for 1994, 1990, 1987, and 1982 High School Graduates.* Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

See appendix table 5-24. *Science & Engineering Indicators – 2000*

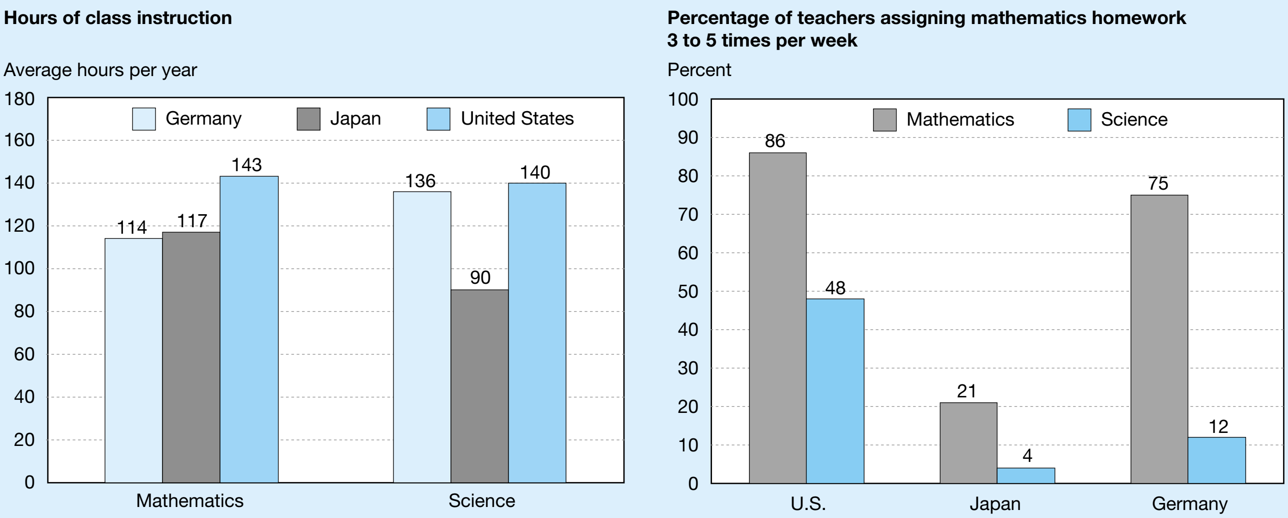
Textbooks reflect the same limitations as documented by curriculum analyses: too many topics with too little coverage and too little development of topics. (See figure 5-17.) Compared to textbooks used in other countries, science and mathematics textbooks in the United States convey less challenging expectations and are repetitive while providing little new information in most grades, a finding reported in earlier research by Flanders (1987) and by Eyelon and Linn (1988). Publishers have made some attempts to reflect the topics and demands conveyed by the educational standards; however, the TIMSS curriculum analyses suggest that when new “standards-referenced” topics are added, much of the old material is retained (Schmidt, McKnight, and Raizen 1997).

Recent studies by AAAS (1999a,b) reinforced the findings of TIMSS and other studies about the limitations of mathematics and science textbooks. AAAS conducted a conceptual analysis of content, based on 24 instructional criteria divided into the following seven categories:

- Identifying/providing a sense of purpose;
- Building on/taking into account student ideas;
- Engaging students in mathematics/engaging students with relevant phenomena;
- Developing mathematical ideas/developing and using scientific ideas;
- Promoting student thinking about mathematics/about phenomena, experience, and knowledge;
- Assessing student progress; and
- Enhancing the mathematics/science learning environment.

The “AAAS Project” presents the 24 criteria used in evaluating middle school science textbooks. Middle school mathematics textbooks were evaluated using parallel criteria. (See sidebar, “AAAS Project.”)

Figure 5-16.
Selected characteristics of grade 8 mathematics and science instruction in Germany, Japan, and the United States: 1994–95



NOTE: Data are from the Third International Mathematics and Science Study.

SOURCE: National Center for Education Statistics (NCES). 1996. *Pursuing Excellence: A Study of U.S. Eighth Grade Mathematics and Science Teaching, Learning, Curriculum, and Achievement in International Context.* NCES 97-198. Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

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The study examined 9 middle-grade science texts and 13 mathematics texts. The samples included the most widely used texts in both subjects. Each text was evaluated by two independent teams of middle-school teachers, curriculum specialists, and science/mathematics education professors. With funding from NSF, AAAS developed and tested the evaluation procedure over a three-year period in collaboration with over 100 scientists, mathematicians, educators, and curriculum developers. On a 0-to-3-point scale (where 3 represents "satisfactory"), all 9 science textbooks scored below 1.5. Six mathematics texts scored below 1.5, while only half that number scored above 2.5 points (AAAS 1999a,b).

Instructional Practice

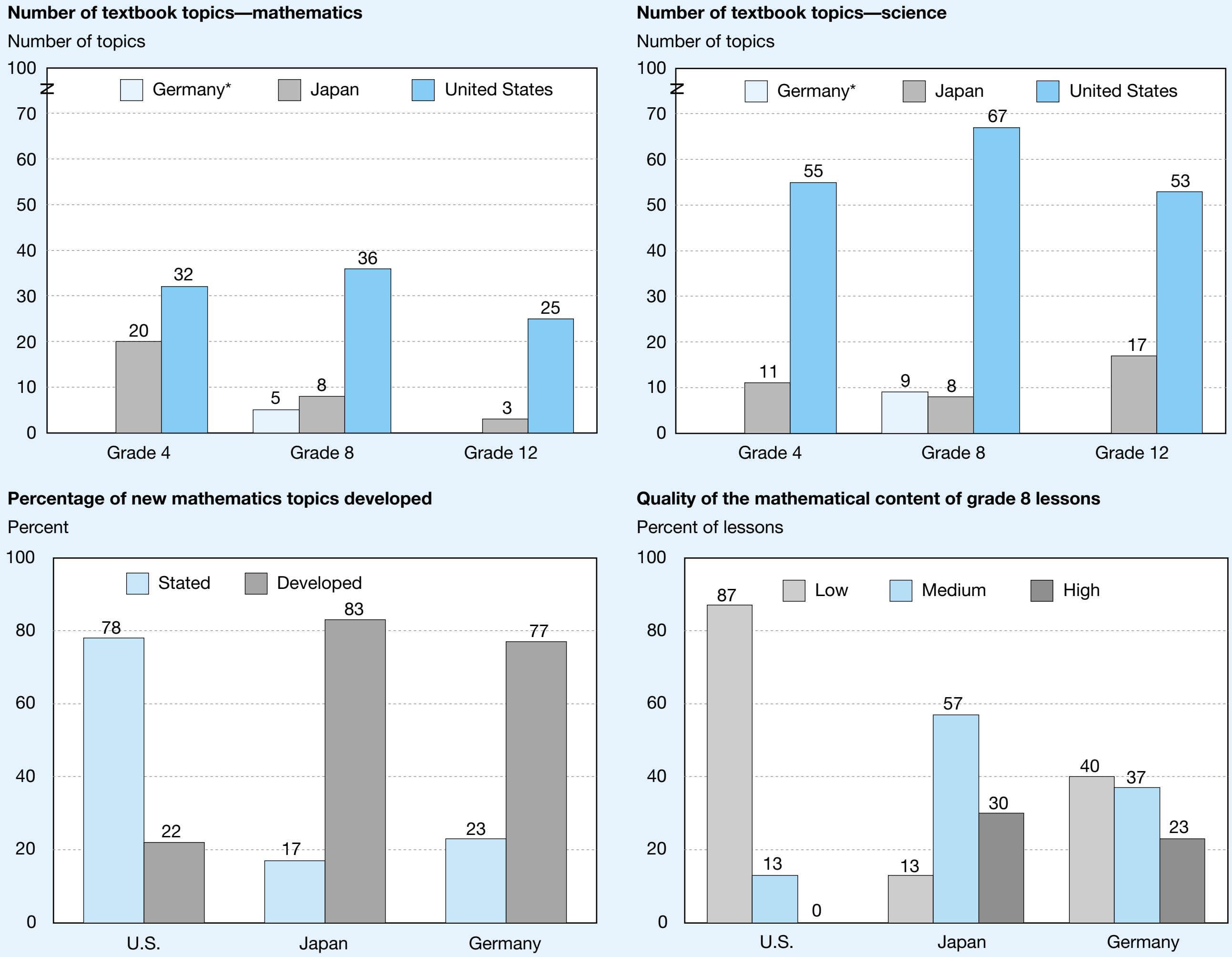
Most information about instructional practice has come from surveys in which teachers were asked about their use of specific aspects of their teaching. In a recent survey, 82 percent of full-time U.S. mathematics teachers and 74 percent of full-time science teachers gave themselves good grades on using practices consistent with educational standards in their fields (NCES 1999a). But classroom observational studies, which have added depth and dimension to depictions of practice, often painted quite a different picture. These studies demonstrated that it is relatively easy for teachers to adopt the surface characteristics of standards-based teaching but much harder to implement the core features in everyday classroom practice (Cohen 1991, Spillane and Zeuli 1999, and Stigler et al. 1999).

The TIMSS video study of grade 8 mathematics instruction is a case in point. Lessons in U.S., German, and Japanese classrooms were fully documented, including descriptions of the teacher's actions, the students' actions, the amount of time spent in each activity, the content presented, and the intellectual level of the tasks students were given in the lesson (Stigler et al. 1999). These findings identified four key points:

- The content of U.S. mathematics classes requires less high-level thought than classes in Germany and Japan;
- U.S. mathematics teachers' typical goal is to teach students how to do something, while Japanese teachers' goal is to help them understand mathematical concepts;
- Japanese classes share many features called for by U.S. mathematics reforms while U.S. classes are less likely to exhibit these features; and
- Although most U.S. mathematics teachers report familiarity with reform recommendations, relatively few apply the key points in their classrooms.

Ratings of instructional quality of mathematics instruction in eighth grade classrooms provided by mathematicians indicated approximately 30 percent of lessons in Japanese classrooms as "high quality" and 13 percent as "low quality." In German classrooms, 23 percent of lessons received high ratings and 40 percent low ratings. In comparison, approximately 87 percent of U.S. lessons were considered low qual-

Figure 5-17.
Selected characteristics of grade 4, 8, and 12 mathematics and science instruction in Germany, Japan, and the United States: 1994–95



*Grade 4 and grade 12 data for Germany not available for this comparison.

NOTE: Data are from the Third International Mathematics and Science Study. Eighth grade algebra texts are not included.

SOURCES: Stigler, J.W., P. Gonzales, T. Kanaka, S. Knoll, and A. Serrano. 1999. *The TIMSS Videotape Classroom Study: Methods and Findings from an Exploratory Research Project on Eighth-Grade Mathematics Instruction in Germany, Japan, and the United States.* NCES 1999-074. Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement; Schmidt, W.H., C.C. McKnight, and S.A. Raizen. 1997. *A Splintered Vision: An Investigation of U.S. Science and Mathematics Education.* Boston, MA: Kluwer Academic Publishers.

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ity and none was considered high quality. (See figure 5-17.) However, due to the small scale of the study, these results are suggestive rather than definitive. The studies are now being replicated on a larger scale in both mathematics and science.

Technology

Throughout the United States, school districts have dramatically increased the access of students and teachers to new forms of technology such as hand-held calculators, desktop computers, and the Internet. Hand-held calculators are owned by almost every student in the United States and are fully integrated into the teaching of mathematics in many U.S. schools. Since 1985, many calculator models have featured built-in graphing software for enhancing teaching and learning by allowing mathematics students to visualize mathematical functions.

The National Council of Teachers of Mathematics (NCTM) Curriculum and Evaluation Standards (NCTM 1989) urges the use of calculators to reduce the time spent on paper and pencil methods of calculating so that students can have more time to work problems that foster development of conceptual power. The NCTM suggests that by using this approach, stu-

AAAS Project

Evaluating the Quality of Middle Grade Science Textbooks

Category I. Providing a Sense of Purpose
- Conveying unit purpose
- Conveying lesson purpose
- Justifying activity sequence

Category II. Taking Account of Student Ideas
- Attending to prerequisite knowledge and skills
- Alerting teacher to commonly held student ideas
- Assisting teacher in identifying own students' ideas
- Addressing commonly held ideas

Category III. Engaging Students with Relevant Phenomena
- Providing variety of phenomena
- Providing vivid experiences

Category IV. Developing and Using Scientific Ideas
- Introducing terms meaningfully
- Representing ideas effectively
- Demonstrating use of knowledge
- Providing practice

Category V. Promoting Student Thinking about Phenomena, Experiences, and Knowledge
- Encouraging students to examine their ideas
- Guiding student interpretation and reasoning
- Encouraging student to think about what they've learned

Category VI. Assessing Progress
- Aligning assessment to goals
- Testing for understanding
- Using assessment to inform instruction

Category VII. Enhancing the Science Learning Environment
- Providing teacher content support
- Encouraging curiosity and questioning
- Supporting all students

SOURCE: American Association for the Advancement of Science (AAAS). 1999a. Project 2061. "Heavy Books Light on Learning: Not One Middle Grades Science Text Rated Satisfactory." Available from <<http://www.project2061.org/newsinfo/press/rlo92899.htm>>.

dents develop a stronger basis for understanding how to approach complex problems. Meanwhile, educators who do not share this view have expressed concern that young children in classrooms where calculators are heavily used may not develop proficiency with the basic arithmetic operations.

Both the NAEP and the TIMSS surveys included questions for teachers and students on their level of calculator use in schools. The TIMSS surveys show that 99 percent of eighth grade students and 95 percent of fourth grade students in the United States own calculators. The range was from 76 percent in Norway to 95 percent in the United States and the Czech Republic. (See text table 5-7.) In the United States, many schools provide calculators for use by students who do not own them. School-owned calculators used in fourth grade U.S. classrooms increased from 59 percent to 84 percent between 1992 and 1996 (Hawkins, Stancavage, and Dossey 1998).

Classroom use of calculators is less common among U.S. elementary school students than it is among middle school students in most countries. Although U.S. teachers are more likely than teachers in most other countries to use calculators in the lower grades, about 30 percent still report that they never use calculators. (See text table 5-7.) On the other hand, about the same percentage of these teachers report using calculators to solve complex problems in fourth grade classrooms, about the same proportion of teachers as in Canada and England.

By grade 8, classrooms in nearly all countries use calculators for mathematics instruction. The extent of calculator use is comparable in most countries, except in South Korea and Ireland, where calculators are seldom used in middle school classrooms. A large percentage of U.S. teachers (about three-fourths) report that they use calculators to help students solve complex problems.

Computers also are becoming ubiquitous in U.S. schools. In the 1997/98 school year, 71 percent of teachers in grades 4 to 12 had students use computers during class time at some point during the school year. (See appendix table 5-26.) Teachers of secondary academic subjects are less likely to have their students use computers than are elementary teachers of self-contained classes or teachers of business and vocational subjects. Overall, about one-half of mathematics teachers (49 percent) reported some use of computers by students during at least one of the classes they taught that year, compared to 75 percent of English teachers. Although computers were introduced to classrooms almost two decades ago, computers are a form of technology that still may be unfamiliar to many teachers. The results of a 1998 survey reported that only one teacher in five felt "very well prepared" to integrate education technology in the subject they taught (NCES 1999b).

In addition to issues of professional development related to computer use, equity issues also have been a concern. A study by the Educational Testing Service (ETS) examined the relationship of achievement on the 1996 NAEP mathematics assessment to computer access, frequency of use, and level of teachers' professional development in technology (ETS 1999). Students who scored the highest among eighth graders were more likely to use computers at home, more likely to have teachers with recent professional development in technology, and more likely to have teachers who used computers to teach higher order thinking skills. In general, the study concluded that the use of computers can be positively associated with student achievement when it is used in productive ways such as increasing use of higher order concepts and when teachers are informed of their use (ETS 1999).

Studies have also found that socioeconomic variables influence computer access (Becker 1997 and ETS 1999). There were few differences in computer use at school among fourth or eighth graders, except that black children in the fourth grade used the computer somewhat more often. Black, poor,

Text table 5-7.
Mean students mathematics scores and percent of students and teachers reporting hand-held calculator use in 4th and 8th grade, by country: 1995

	Mathematics scores		Fourth grade				Eighth grade teachers		
			Student		Teacher				
Country	4th grade	8th grade	Percent having calculators in home	Never use calculator in math class	Never use in class	Use to solve complex problems	Never use	Use every day	Use to solve complex problems
Singapore	625	643	93	96	97	1	1	82	82
Korea	611	607	87	93	86	3	76	1	4
Netherlands	577	541	93	90	85	2	0	81	67
Czech Republic	567	564	95	63	54	8	3	74	80
Austria	559	539	91	96	98	0	2	87	70
Ireland	550	527	86	91	88	3	68	11	7
United States	545	500	95	34	29	26	8	62	76
Hungary	548	537	88	90	78	5	29	60	53
Canada	532	527	87	51	37	23	5	80	86
England	513	506	93	15	8	28	0	83	73
Norway	502	503	76	89	93	1	2	82	72
New Zealand	499	508	90	18	5	50	7	66	70

SOURCES: Mullis I., M. Martin, A. Beaton, E. Gonzalez, D. Kelly, and T. Smith. 1997. *Mathematics Achievement in the Primary School Years: IEA's Third International Mathematics and Science Study (TIMSS)*. Chestnut Hill, MA: Boston College, TIMSS International Study Center; Beaton, A., M. Martin, I. Mullis, E. Gonzalez, T. Smith, and D. Kelly. 1996a. *Mathematics Achievement in the Middle School Years: IEA's Third International Mathematics and Science Study (TIMSS)*. Chestnut Hill, MA: Boston College, TIMSS International Study Center.

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urban, and rural students in eighth grade were less likely to have access to a computer at home, less likely to have teachers who use computers for learning higher order skills, and less likely to have mathematics teachers who had participated in professional development related to technology in the five prior years (ETS 1999).

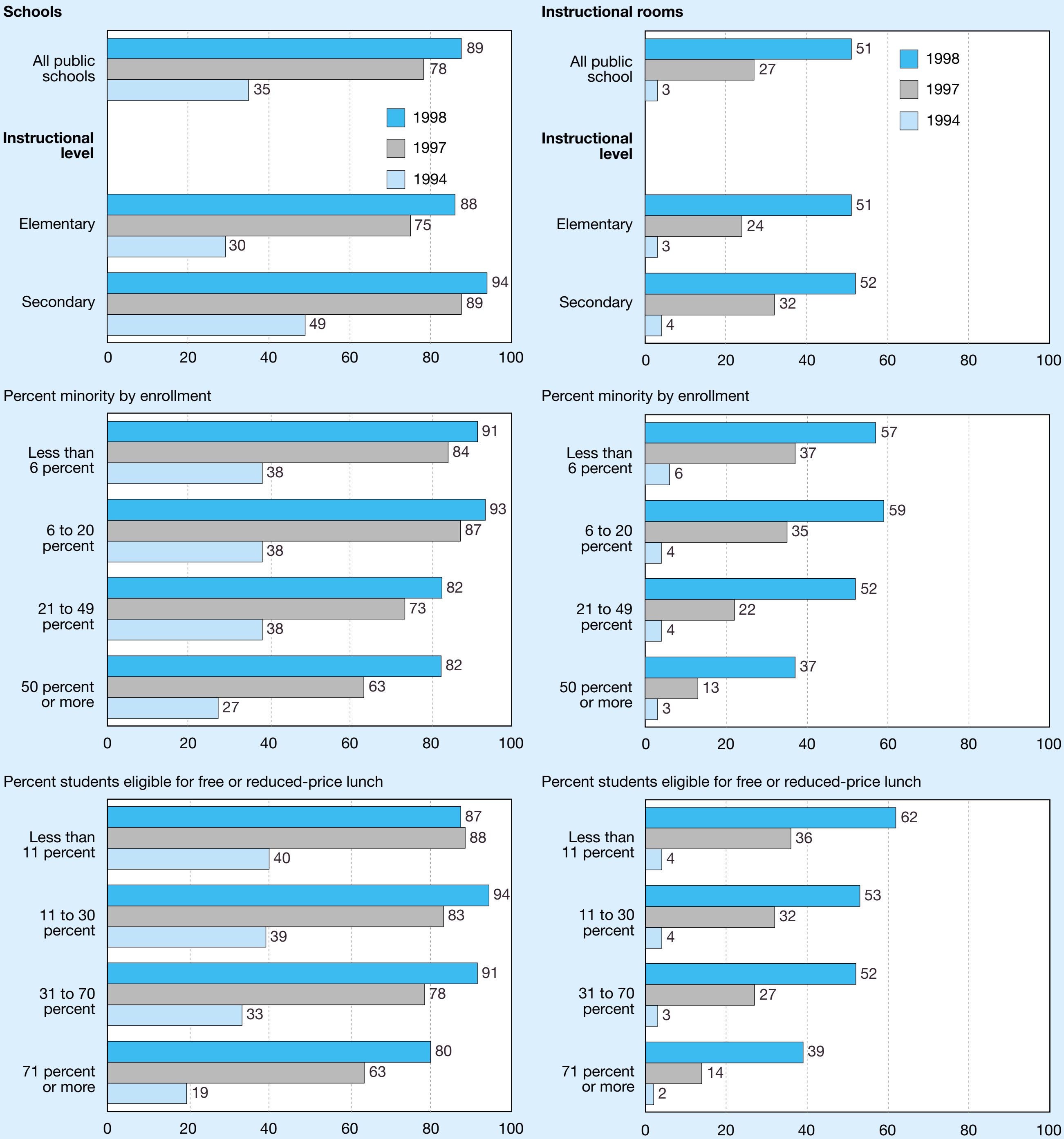
Until recently, "technology in schools" meant computers. Presently the newest technology being explored in schools is the Internet. By 1998, about 90 percent of all schools reported they had access to the Internet, an increase of about 15 percentage points each year since 1994, when 35 percent of schools reported Internet connectivity. (See figure 5-17.) However, for some of these schools only one computer was linked to a single phone line. It is remarkable, therefore, that about half of classrooms had access to the Internet in 1998 (NCES 1998d, Becker 1999a,b). (See also chapter 9, "Significance of Information Technologies.")

Another recent study showed that teachers with several computers in the classroom are much more likely to perceive the value of the Internet and to use the Internet for student research projects (Becker 1999a). However, results also showed that mathematics teachers are the least likely of all teachers to perceive Internet use as having value for classroom instruction. Only about 12 percent of mathematics teachers used the Internet themselves compared with 20 percent of other teachers (Becker 1999a,b). Even as access to computers and other forms of technology in the classroom has increased rapidly, newspaper reports suggest that many teachers (75 percent of those responding to an *Education Week* survey) believe that there were still not enough Internet-connected computers in the classroom to make good use of them for instruction (*Education Week* 1999).

Figure 5-18 suggests that although there has been rapid growth in Internet access and use in all types of schools, there also are equity issues to be resolved. In Fall 1998, about 90 percent of schools at the lowest poverty levels had Internet access, compared to 80 percent at the highest poverty levels (based on the percentage of students receiving reduced-price lunches). Although the percentage of classrooms with Internet connections also increased greatly in one year for all categories of schools, inequities were apparent at this level as well. In Fall 1998, 40 percent of classrooms in high poverty schools had Internet access, compared to 62 percent of classrooms in low poverty schools. Unequal access to the Internet in schools has led many educators and policymakers to be concerned about developing a "digital divide" that separates poor and minority children from more affluent and white children.

In summary, at the beginning of a new century, classrooms are clearly undergoing a transformation. The rapid changes make descriptions of a "typical" classroom based on survey results a few years old already out of date. More detailed discussion of the growth of information technologies in schools and a review of their effectiveness in education are included in the chapter on information technology.

Figure 5-18.
Percentage of public schools and percentage of instructional rooms having access to the Internet, by school characteristics: 1994, 1997, and 1998



SOURCES: National Center for Education Statistics (NCES). 1995. *Advanced Telecommunications in U.S. Public Schools, K-12.* NCES 95-731; 1996. *Advanced Telecommunications in U.S. Public Elementary and Secondary Schools, 1995.* NCES 96-854; 1997. *Advanced Telecommunications in U.S. Public Elementary and Secondary Schools, Fall 1996.* NCES 97-944; 1998. *Internet Access in Public Schools.* NCES 98-031. Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement; and data from the Fast Response Survey System, "Survey on Internet Access in U.S. Public Schools, Fall 1998," FRSS 69, 1998.

See appendix table 5-25.

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Teachers and Teaching

Currently, there are approximately 2.7 million teachers in U.S. public schools: 1.6 million in primary schools and 1.1 million in secondary schools. (See text table 5-8.) By the year 2009, the number of public elementary and secondary teachers is projected to increase by 2.4 percent. (See text table 5-9.) One question facing the education community is whether supply will be sufficient to meet demands in the next ten years. The U.S. Department of Education projects that 2 million teachers will need to be hired in the next 10 years (NCES 1999f). Some analysts maintain that teacher preparation programs will not graduate enough teacher candidates to meet this demand. Others disagree and point out that the critical question is not whether there will be enough teachers to satisfy demand, but enough to assure that every child and every classroom has a competent teacher (Darling-Hammond 1996).

Another aspect of the supply and demand problem for the teaching profession is related to societal changes that have taken place in recent years. As noted earlier, the school population has increased in diversity. From this perspective, the composition of the current teaching force has not kept pace. In 1976, nearly 88 percent of public school teachers were white; in 1996, the estimate was 91 percent (NCES 1997a). Consistent with these numbers, a 1996 survey of state departments of education reported that few students have the opportunity to study science and mathematics with minority teachers: only 14 percent of students taking mathematics and biology, 10 percent taking chemistry, and 7 percent taking physics (Blank and Langeson 1997).

The gender balance in the teaching force has been a matter of interest for some time as well because of the lower representation of women in some areas of science noted earlier in this chapter (NSF 1997a,b). There has been some change in the last two decades, but not always in the desired direction. From 1976 to 1996, the percentage of male teachers increased from 33 percent to 42 percent. In 1985, two-thirds of mathematics and science teachers were male. More recent surveys suggest that the balance is shifting toward equality in the numbers, except in physics, where currently 72 percent of teachers are male (NCES 1998b).

Text table 5-8.
Classroom teachers in public elementary and secondary schools: 1985–2009
(Thousands)

Year	K–12	Elementary	Secondary
1985	2,206	1,237	969
1990	2,398	1,429	969
1995	2,598	1,525	1,073
1999[a]	2,700	1,580	1,120
2000[a]	2,712	1,583	1,129
2005[a]	2,765	1,581	1,184
2008[a]	2,768	1,578	1,190
2009[a]	2,766	1,578	1,188

[a]Projected.

SOURCE: National Center for Education Statistics (NCES). 1999. *Projections of Education Statistics to 2009.* NCES 1999-038. Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

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Teacher Qualifications

As new standards for mathematics and science education create higher expectations for student achievement, more is expected of teachers as well. These higher expectations raise the question of what high quality teaching entails. In the absence of completely satisfactory measures of quality, indicators of teacher preparation and qualifications have been used as proxies. Studies show that teacher qualifications make a real difference to achievement.

Results from the 1996 NAEP survey of teachers showed that students with higher mathematics scores were more likely to have teachers who were certified, had more than five years of teaching experience, and, in the case of eighth grade students, had majored in mathematics rather than in any field of education (Hawkins, Stancavage, and Dossey 1998). In science, the results were similar. Students with better achievement had teachers who had college majors in science, were certified in science (eighth grade only), and had more years of teaching experience (O'Sullivan, Weiss, and Askew 1998). Earlier studies also reported a positive relationship between achievement and teacher qualifications (Chaney 1995).

Other studies have confirmed the strength of the relationship between achievement and teacher characteristics. One of those studies demonstrated that, with socioeconomic status controlled, performance differences between white and black students could be explained largely by differences in their teachers' qualifications (Ferguson 1991). Analyses of other data further suggest that better achievement results are obtained when resources are spent to improve the quality of teaching than when the same resources are applied to options such as reducing class size or raising teachers' salaries (Ferguson 1991; Greenwald, Hedges, and Laine 1996).

Degrees Earned

TIMSS survey data indicated that mathematics and science teachers in U.S. schools completed more years of college than their counterparts in most other countries (NCES 1996a, 1997b). A 1998 survey of full-time teachers showed that, in fact, almost all had undergraduate degrees and many had master's or other advanced degrees as well. Overall, approximately 55 percent of high school teachers, 46 percent of middle school teachers, and 40 percent of elementary school teachers held master's degrees (NCES 1998b). Among secondary mathematics and science teachers, approximately 45 percent had advanced degrees, as was true for teachers of other core subjects including English and social studies (NCES 1998b).

Text table 5-9.
Percentage of public secondary school (grades 7–12) teachers in each field without a major or a minor in that field and students taught by those teachers

	English	Math	Science	Life sciences	Physical sciences	Social studies	History
Teachers							
Total	24.1	31.4	19.9	32.9	56.9	19.3	53.1
School poverty level							
Low poverty	20.1	26.8	17.5	29.2	51.3	15.8	46.4
High poverty	25.7	42.8	27.8	40.1	65.1	25.1	60.0
School size							
Small	30.4	41.2	25.5	38.1	64.5	25.5	62.8
Large	22.4	27.5	17.6	30.1	53.7	17.2	48.1
Students taught by teachers							
Total	20.8	26.6	16.5	38.5	56.2	13.4	53.9
Track of class							
Low track	24.7	33.5	20.4	42.3	66.8	14.3	55.1
Medium track	11.8	15.7	9.2	31.4	42.8	8.9	44.9
High track	11.2	20.4	7.2	20.7	43.0	11.2	51.1
Grade level of class							
7th grade	32.2	48.8	31.8	60.4	73.8	23.9	56.3
8th grade	32.9	37.1	23.8	32.9	75.7	19.7	60.5
9th grade	15.7	18.1	10.7	27.9	61.7	8.7	48.7
10th grade	11.1	16.8	8.9	29.3	45.7	8.8	51.1
11th grade	11.2	15.9	6.4	23.5	36.8	6.8	47.0
12th grade	13.9	24.2	13.1	25.3	41.0	11.3	62.4

SOURCE: Ingersoll, R. 1999. "The Problem of Underqualified Teachers in American Secondary Schools." *Educational Researcher* 28, No. 2 (March): 26–37.

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Undergraduate Major

The importance of teachers' academic preparation in undergraduate years has increased as educational standards are more widely adopted. To help students meet high standards, teachers must have a thorough knowledge of their subject matter and a solid understanding of concepts in their fields. Until recently, most states did not require teachers to have academic majors in the fields in which they most often taught.

A 1996 NAEP survey found that the majority of mathematics and science teachers do not have academic degrees in their fields. The data showed that 83 percent of fourth grade students and 32 percent of eighth grade students had mathematics teachers who had college majors in education. Nine percent of fourth graders and 49 percent of eighth graders have teachers who majored in mathematics. Four and 13 percent of these students, respectively, had teachers with a major in mathematics education. NAEP survey data showed that 74 percent of fourth grade students and 20 percent of eighth grade students had science teachers who majored in education (excluding science education). Five percent of fourth grade students and 45 percent of eighth grade students had science teachers who majored in science. Five and 11 percent of these students, respectively, had teachers who majored in science education.

Examining data from another perspective, 1996 NAEP survey findings indicated that only 9 percent of fourth grade students had teachers who majored in mathematics and an additional 4 percent had teachers who majored in mathematics education. Approximately 49 percent of eighth grade students were taught by teachers with degrees in science and 13 percent by teachers with degrees in science education (NCES 1998c).

Experience

Teaching experience is another widely used quality indicator. The 1998 NCES teacher survey showed that the majority of full-time teachers had 10 or more years of experience in their profession (NCES 1999b). Results of the 1996 NAEP survey showed that one-half of the students taking mathematics and science in grades four and eight had teachers who had been in the profession 11 years or longer. An important concern raised by the National Commission on Teaching and America's Future is that teachers with the least experience often are placed in central city schools, where the need for experienced teachers may be greatest (NCTAF 1996).

Certification

Certification is also a factor in determining a teacher's qualifications to teach in a particular field. The 1996 NAEP surveys reported that approximately 32 percent of fourth grade and 81 percent of eighth grade students study mathematics with a teacher certified in mathematics. Close to 25 percent of fourth grade students and 75 percent of eighth grade students study science with teachers certified in some area of science or in science education. Certification and licensing have been contentious issues in the profession for some time now. The National Commission on Teaching and America's Future estimated that, in recent years, approximately 50,000 people have entered classrooms with emergency or substandard licenses (NCTAF 1996).

In- and Out-of-Field Teaching Assignments

Often, secondary school teachers are assigned to courses for which they lack certification or other appropriate preparation. "Out-of-field" teaching is the term applied to this practice. Estimates of the extent of out-of-field teaching vary depending on the criteria used. For example, when the criterion for teaching is a graduate degree in the subject taught, the incidence of out-of-field teaching in mathematics and science is quite high. When the criterion is certification alone, estimates drop to less than 15 percent for both subjects (NCES 1997a). Ingersoll, who has done the most extensive examinations of this phenomenon, defines out-of-field teaching in terms of undergraduate major and minor (Ingersoll 1996, 1999).

Using Ingersoll's definition, out-of-field teaching is most common in physical science (57 percent) and history (53 percent), followed by life sciences and mathematics (33 percent and 31 percent, respectively). (See text table 5-9.) Out-of-field teaching is more common in small schools and in schools with larger numbers of low income or minority students. (See figure 5-19.) Students in lower secondary grades (7 through 9) and students in lower academic tracks experience more out-of-field teaching than students in higher grades and higher ability tracks. Out-of-field teaching is also more widespread in some states than in others (Ingersoll 1996).

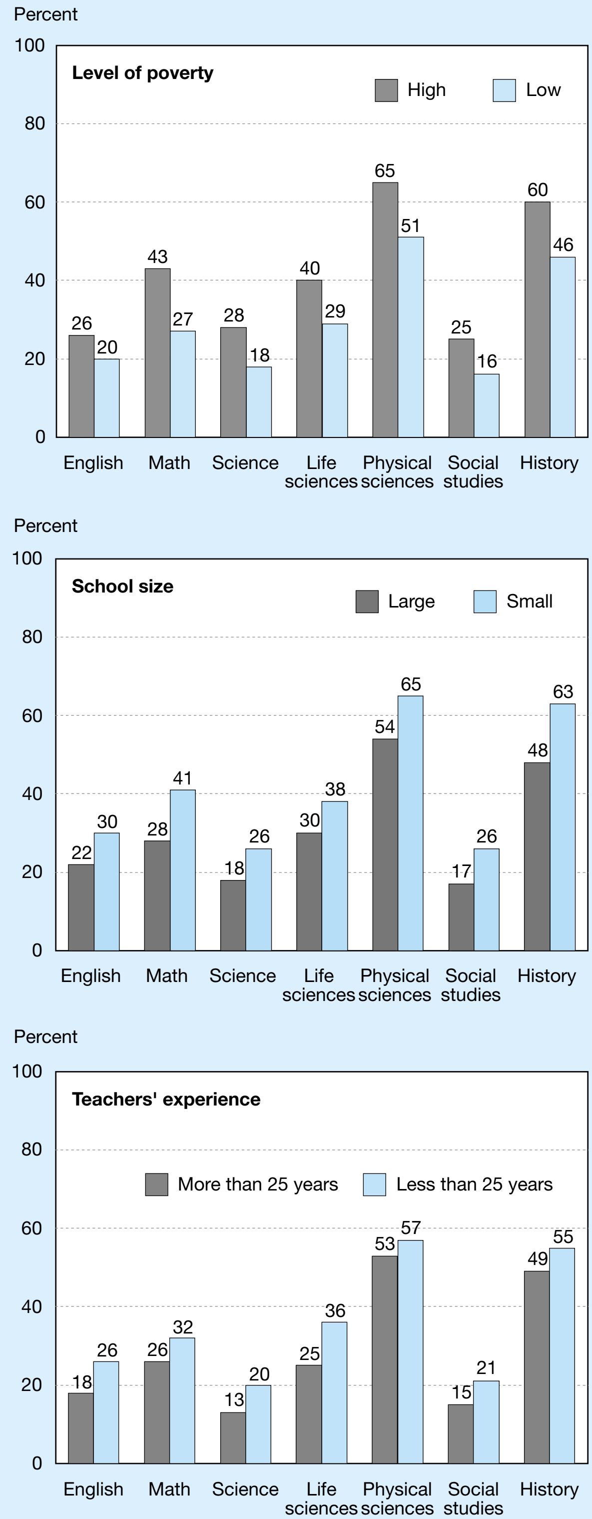
Out-of-field teaching is a major concern to the profession because it is a factor contributing to the number of teachers who are not appropriately prepared for the subjects they teach. Equity issues also fuel these concerns because poor and minority children are more often faced with teachers who are working outside their areas of preparation and expertise (Ingersoll 1996, NCTAF 1996, and Ingersoll 1997).

These findings are consistent with those of a recent study on teachers' perceived preparedness to function in various areas. While 71 percent of teachers feel well prepared to maintain order and discipline in their classrooms, over 36 percent feel well prepared to implement state or district curriculum and performance standards and only 20 percent were prepared to address the needs of limited English proficiency students or students from diverse cultural backgrounds (NCES 1999b).

The Teaching Profession in the 21st Century

Teachers, teacher educators, and state departments of education have been working for at least two decades to upgrade the quality of teaching. Some states and teacher preparation

Figure 5-19.
Percentage of secondary school (grades 7–12) teachers in each field without a major or a minor in that field



SOURCE: Ingersoll, R. 1999. "The Problem of Underqualified Teachers in American Secondary Schools." *Educational Researcher* 28, No. 2 (March): 26–37.

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programs now require teacher candidates to major in an academic subject. Teacher preparation programs are working with school districts to provide candidates with an additional one or two years of study, focused primarily on classroom experience. Induction programs are being developed to provide new teachers with mentors and support during their early years, when the recruits are most likely to leave the profession.

A new teacher education infrastructure is being developed. Standards for accrediting teacher preparation programs have been developed by the National Commission on Accreditation in Teacher Education (NCATE). Standards for licensing beginning teachers and guiding professional development have been formulated by the Interstate New Teachers Assessment and Support Consortium (INTASC), a collaboration of state-level staff and professional organizations concerned with teacher preparation and licensing. Standards for certifying accomplished teaching are being developed by the National Board for Professional Teaching Standards. As envisioned, these standards, aligned closely with each other and with standards for student learning, will form an integrated system that carries the prospective teacher from entry into a teaching program, through licensing and certification, through becoming an accomplished teacher, and on to lifelong professional development (Wise 1989, INTASC 1991, NBPTS 1991, INTASC 1994, Wise and Leibrand 1996, and Darling-Hammond and Ball 1997).

In addition to resolving questions about teacher qualifications, the profession also must resolve equity issues related to the quality of instruction for students in different circumstances. Poorer schools and schools with more minority students are less likely to have qualified teachers when judged by major, certification status, or years of teaching experience. Minority students are less likely to have teachers who are judged as very effective when evaluated using value-added criteria that reflect student growth in achievement (Education Trust 1998). This fact has important policy consequences. Students with the greatest need often are placed in the care of teachers who are least prepared to provide the kind of support they require (Holmes Group 1986; Oakes, Gamoran, and Page 1992; Chaney 1995; Ingersoll 1995, 1996, 1997, 1999).

Conclusion

This chapter presented indicators of changes in U.S. elementary and secondary schools in student achievement, curriculum, instructional practices, and the teaching profession. Observations made about U.S. mathematics and science education in 1947 noted that textbooks were thick and included unnecessary information and that teachers did not have sufficient training in mathematics. Significant efforts have been made to reform elementary and secondary schools since 1947 such as those stimulated by Sputnik in 1957, the National Commission on Excellence in Education 1983, and the National Education Goals that grew out of the Governor's summit of 1990. The national policy goals and educational standards for mathematics and science education set new and higher expectations for U.S. schools, students, and teachers. In the 1990s, NSF carried out a program of systemic reform to seek improved methods of education. The indicators in this chapter were chosen to measure how close the Nation has come to meeting those expectations.

A higher proportion of students graduate from high school having taken advanced courses in mathematics and science than did their counterparts three decades ago. As measured by the National Assessment of Educational Progress, student achievement in mathematics and science has increased since the mid-1970s, but little change has occurred since 1990. The achievement of students in most demographic groups has improved significantly since the late 1970s. Much of that improvement, however, has been in lower skill areas. There have been small increments in the proportion of students achieving at higher levels of performance, but not nearly enough to conclude that National Education Goal 3 has been well met. Many students leave elementary and middle school without strong foundations in mathematics and science. This is a particular concern when regarding black and Hispanic students who continue to perform far below their white counterparts.

The performance of females compared with males on tests of mathematics and science has changed somewhat during the past two decades. At elementary school, few significant differences in performance levels for either mathematics or science were observed in 1996, the last year NAEP was available. At middle school, no differences are detectable for mathematics, but some difference between genders exists in science. At high school, the tendency of males to outperform females is still detectable in mathematics and clearly evident in science, although the differences have been narrowing since 1977.

Among the National Education Goals is the assertion that the mathematics and science achievement of U.S. students will be first in the world by the year 2000. Fourth grade students come close to meeting this expectation in both subjects, but grade 8 and grade 12 U.S. students perform below their peers in other countries according to results collected in 1995 for the Third International Mathematics and Science Study (TIMSS).

An explicit goal of educational standards for mathematics and science is that all students—without regard to gender, race, or income—participate fully in challenging coursework and achieve at high levels. The disparate performance among racial/ethnic groups is still observed in NAEP assessments. Asian/Pacific Islander and white students are better represented in advanced courses than are black and Hispanic students. Asian/Pacific Islander and white students continue to outperform black and Hispanic students. Students of color and less-affluent students still have less access to high-end technology and less access to teachers with the proper education and certification in the subjects they teach. Although differences among ethnic groups continue, there have been important improvements: black and Hispanic students are now taking more advanced courses in high school, their performance on mathematics and science achievement tests has improved substantially, and discrepancies among racial/ethnic groups have narrowed in some cases in the last two decades.

The role of education technology in U.S. schools has been changing rapidly. Hand-held calculators are commonly used in both U.S. homes and classrooms. About one-fourth of fourth grade teachers and three-fourths of eighth grade teachers report that they use calculators for solving complex problems. By 1998, nearly all schools reported that at least one computer was linked to the Internet and half of the classrooms had access to the Internet. Computers are less often used in mathematics classes than in other subjects. Teachers who had several computers in their classroom were the most likely to report that the Internet was of use to them for student research projects, but at the same time, only about 20 percent of teachers feel "very well prepared" to integrate technology into the subjects they teach.

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